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TECHNICAL NOTE

U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

RAINFALL SIMULATORS

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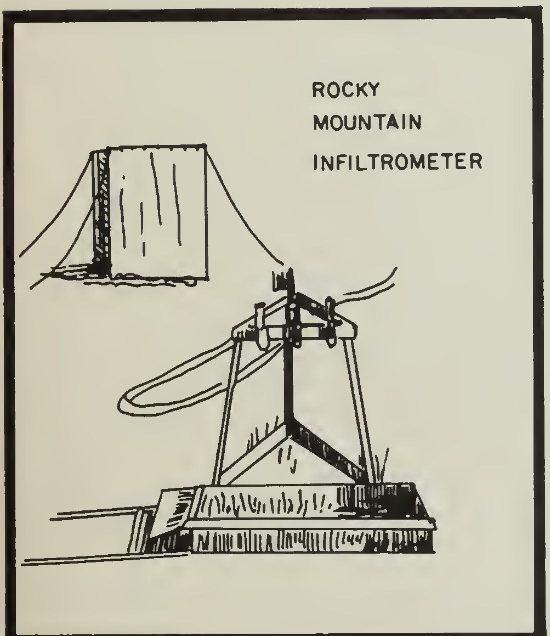


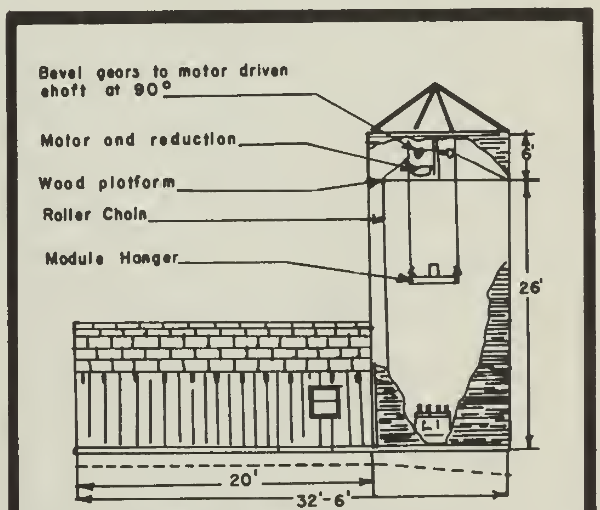
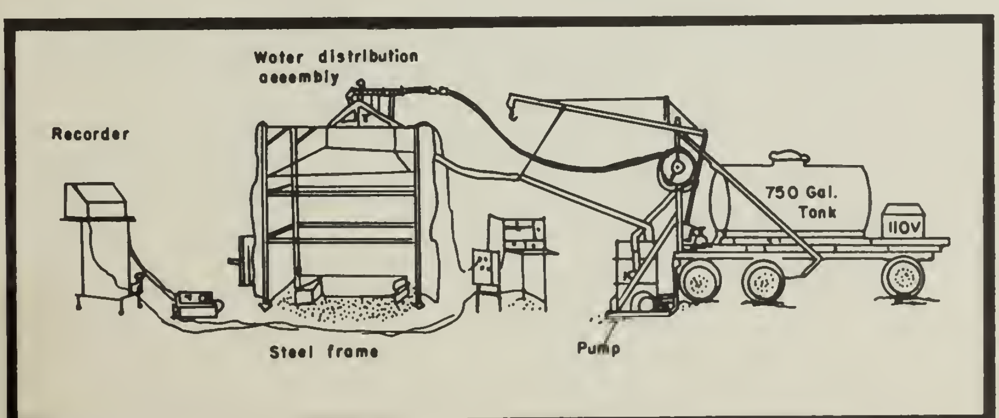


Fig.1 Drop Tower with Associated Work Area



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INTRODUCTION

The purpose of this bibliography is to provide personnel of the Bureau of Land Management with a comprehensive annotated list of articles, books, manuscripts, etc. on rainfall simulators. All of the articles reviewed are available from the Bureau of Land Management Library at the Denver Federal Center in Denver, Colorado. Many of the articles will also be available at public and university libraries.

Several items of importance were considered in reviewing these articles. These include: plot size, portable or laboratory, rate (intensity), rainfall distribution, energy, and raindrop size. The location of the work is given at the end of each heading. At the end of each review is given the number of references used by the author(s). The articles are arranged in alphabetical order according to the last name of the senior author.

At the end of this paper is a bibliography of references cited but not annotated.

AUTHOR	DATE	PLOT SIZE	RATE	DROP SIZE	DIST. ENERGY	PORT-ABLE	LOCATION
Adams, Kirkham & Nielson	1957	14.6 cm dia.		5.6 mm		Port	Iowa
Alfaro & Hachum	1977						Utah
Amerman, Hillel & Peterson	1970		< 1 mm/hr			Port	Wisconsin
Anderson, Stewart & Gregory	1968	4.88x6.10 m	10.16 cm/hr 20.32			Port	New Mexico
Barnett & Dooley	1972	4.27x10.67 m	6.35 cm/hr		75%	Port	Georgia
Befani et al	1969						USSR
Bertrand & Parr	1961	1.16x1.16 m	6.35 cm/hr 8.26 11.43	> 1 mm		Port	Indiana
Bertrand & Sor	1962		4.06 cm/hr 7.11 10.16			Port	Indiana
Beutner, Gaebe & Horton	1940	1.83x7.32 m	7.62 cm/hr 15.24	1.6 mm		Port	Arizona
Black	1972	1.83x1.83 m	39.62-118.67 cm/hr				New York
Blackburn	1975	.91x.91 m & variable	7.62 cm/hr			Port	Nevada
Blackburn	1973	.91x.91 m & variable	3.81 cm/hr 7.62		72%	Port	Nevada

AUTHOR	DATE	PLOT SIZE	RATE	DROP SIZE	DIST. ENERGY	PORT-ABLE	LOCATION
Blackburn, Meeuwig & Skau	1974	.91x.91 m & variable	.508-8.38 cm/hr		70%	Port	Nevada
Blackburn & Skau	1974	.91x.91 m	7.62 cm/hr			Port	Nevada
Bovey & Diaz-Colon	1969		2.54 cm/min				Puerto Rico
Brazil	1976		13 mm/hr 28 58 108			Lab	Colorado
Brockman, Duke & Hunt	1975		1.7-28.2 cm/hr			Lab	New York
Bubenzer & Jones	1971			2.2 mm 3.2 4.9			Illinois
Buckhouse & Gifford	1976	$.23m^2$	7 cm/hr			Port	Utah
Busby	1977	$0.24m^2$	7.5-12.5 cm/hr	Larger	Less	Port	Utah
Chow & Harbaugh	1965	12.19x 12.19 m	1.85-33.02 cm/hr	3.2 mm	0.042-0.725 ft/sec	Lab	
Cluff & Boyer	1971	Comparison of rotadisk with natural rainfall, same as natural rain of 2 in/hr					
Cluff, Evans & Morse	1972	1.5x1.5 m	1.47 cm/hr 4.27			Port	Arizona
		9 cm x 25 cm	3.68 cm/hr			Lab	

AUTHOR	DATE	PLOT SIZE	RATE	DROP SIZE	DIST. ENERGY	PORT-ABLE	LOCATION
Costin & Gilmour	1969	3.05x1.83 m	320 points/h	1.3 mm	26 ft/sec^{-1}	Port	Australia
Craddock & Pearse	1938	2.01x10.06 m	4.45-4.70 cm/hr			Port	Idaho
Dangler & El-Swaify	1976	83.6 m^2	6.35 cm/hr			Port	Hawaii
Dangler, El-Swaify, Ahuja & Barnett	1976		3.18 cm/hr 6.35 12.70			Port	Hawaii
Disrud & Krauss	1971		1.93-3.89 cm/hr		95%	Lab	Kansas
Doran & Andersen	1975	2.3 cm band	4.8 cm/hr			Lab	Minnesota
Dortignac	1951	.76 sq m	6.35-13.97 cm/hr			Port	
Dortignac & Love	1961	.76 sq m	11.43 cm/hr			Port	Colorado
Epstein & Grant	1966	4-30.48x 30.48 cm		3.2 mm 5.1 mm		Lab	Maine
Epstein & Grant	1967	305 cm^2	63.5 mm/hr	3.2 mm		Lab	Maine
Farmer	1973	.76 sq m	7.5 cm/hr 150	0.5-5 mm	92% & 96%	Port	Utah
Farmer & Van Haveren	1971	122.24 x 46.04 cm	7.62 17.78 cm/hr	0.5 mm-5.0 mm		Lab	
Gabriels & DeBoodt	1975		4 mm/hr + vary 7 64.5	varied		Lab	Belgium
Gifford & Hawkins	A critical review						

AUTHOR	DATE	PLOT SIZE	RATE	DROP SIZE	DIST. ENERGY	PORT-ABLE	LOCATION
Gifford & Tew	1969	.76 sq m	6.86 cm/hr+			Port	Utah
Hall	A critical review						
Harris	1972	15.7x17.8 cm				Ring	Wisconsin
Hermsmeier, Meyer, Barnett & Young	1963	varied	3.18 6.35 12.70 cm/hr		80%	Port	
Holland	1969	600 sq m	variable			Lab	Colorado
Jager	1972	16.76 sq m	9.40 cm/hr			Port	Nevada
Kelling & Peterson	1975		12 cm/hr			Port	Wisconsin
Kilinc & Richardson	1973	1.52x4.88 m	3.18-11.68 cm/hr			Lab	Colorado
Kinnell	1974	1 m^2	varied	$>$ 3.8 mm	98%	Lab	Australia
Lattanzi, Meyer & Baumgardner	1974	61x61 cm	6.4 cm/hr				Indiana
Law	1977	Statistical Evaluation					
Lusby		.1 acres	5.08 cm/hr			Port	Colorado
Lusby & Toy	1976	1,066.80 m	5.08 cm/hr			Port	Wyoming
Lyles, Disrud & Woodruff	1969		1.6-5.61 cm/hr		0.14-0.18 kg/cm^2	Lab	Kansas
Mazurak, Chesnin & Tiarks	1975	7.6 cm dia.	3 cm/hr 7 12	5.1 mm		Lab	Nebraska

AUTHOR	DATE	PLOT SIZE	RATE	DROP SIZE	DIST. ENERGY	PORT-ABLE	LOCATION
Mazurak & Mosher	1968	95 cm circum.	2-12 cm/hr	5.1 mm	95%	Lab	Nebraska
McQueen	1963	76.12 sq cm	2.54-38.10 cm/hr	5.6 mm	0.137 joules/ cm^2/cm	Port	Washington
Meeuwig	1969	50.80x76.20 cm	6.35 cm/hr				Utah
Meyer	1963	A review					Indiana
Meyer	1960	varied	6.35 cm/hr 12.70		80%	Port	Indiana
Meyer & Harmon	1977	Explained through graphs					Mississippi
Meyer & McCune	1958	4.57x3.66 m	6.35 cm/hr 12.70		75%	Port	Indiana
Meyer, Wischmeier & Daniel	1971	3.66 m x 10.67 m	6.35 cm/hr			Port	
Moldenhauer & Long	1964		3.43-6.78 cm/hr	4.84-5.00 mm		Lab	Iowa
Moldenhauer, Lovely, Swanson & Currence	1971	10.67 m long	6.35 cm/hr			Port	Iowa
Morin, Cluff & Powers	1970	2.1 m dia.	17-152 mm/hr				Arizona
Morin, Goldberg & Seginer	1967	1.5 sq m	8-143 mm/hr			Port	Israel

AUTHOR	DATE	PLOT SIZE	RATE	DROP SIZE	DIST. ENERGY	PORT-ABLE	LOCATION
Munn & Huntington	1976	61x61 cm	up to 23 cm/hr	3.2 mm	1.7×10^6 joules/ha-cm	Port	California
Munn, McLean, Ramirez & Logan	1973	122x30.4 cm	6.35 cm/hr 12.7			Port	Ohio
Mutchler & Hermsmeier	1965	Nozzle		2-1/8 mm	80%	Nozzle	Minnesota
Obeid & Din	1971						Sudan
Packer	1957	2.74x2.74 m	up to 15.24 cm/hr			Port	
Rauzi & Smith	1973	.61 m sq	6.35-8.89 cm/hr		75%	Port	Colorado
Rawitz, Margolin & Hillel	1972					Port	Israel
Römkens, Glen, Nelson & Roth	1975	100 cm^2	varied	varied		Lab	Indiana
Rose	1960		5.08 cm/hr 10.16 15.24	3.2-6.2 mm		Lab	Uganda
Selby	1970	14 cm dia.	20-300 mm/hr			Port	New Zealand

AUTHOR	DATE	PLOT SIZE	RATE	DROP SIZE	DIST. ENERGY	PORT-ABLE	LOCATION
Sloneker & Moldenhauer	1973	61 m^2	2.4 cm/hr 4.3 8.4		21107.2 joules/m^3	Port	Minnesota
Sloneker, Olson & Moldenhauer	1974	Measuring technique for soil-water pressure, simulator same as above					Minnesota
Steinhardt & Hillel	1966	70x70 cm	4-100 mm/hr	varied		Port	Israel
Swanson	1965	2-10.67 x 4.27 m	6.35 cm/hr 12.70			Port	Nebraska
Swanson & Dedrick	1967	10.67x3.66 m	6.35 cm/hr			Port	Nebraska
Swartzendruber & Hillel	1975	1 m^2	1.037 mm/min			Port	Israel
Tromble, Renard & Thatcher	1974	129.54 sq cm	4.45 cm/hr			Port	Arizona
Turner & Langlord	1969	4-4.57 x 4.57 m	med			Lab	Australia
White, Asmussen, Hauser & Turnbull	1976	3-4 row (30.2 m^2)	16.5 cm/hr			Port	Georgia
Williams & Gifford	1969	3.05 m dia		3.2-5.0 mm		Port	Utah
Wischmeier & Mannering	1965		6.35 cm/hr			Port	Indiana
Yen & Chow	1969	9.75 sq m	8.89 cm/hr 17.02	3.56 mm		Lab	Illinois

AUTHOR	DATE	PLOT SIZE	RATE	DROP SIZE	DIST. ENERGY	PORT-ABLE	LOCATION
Yerkhov	1975						USSR
Young & Burwell	1972	22.13x4.06 m	3.18 cm/hr 6.35 12.70		84% 76% 70%	Port	Minnesota
Young & Mutchler	1969	4.06x22.89 m	6.35 cm/hr			Port	South Dakota
Zingg	1940	2.44 m 1.07x4.88 m	8.00 cm/hr			Lab	Missouri

Adams, J. E.; Kirkham, D.; and Nielson, D. R. 1957. A Portable Rainfall-Simulator Infiltrometer and Physical Measurements of Soil in Place. Soil Science Society Proceedings. 21(5): 473-477. Iowa.

A portable rainfall-simulator and infiltration cylinder are described for applying artificial rainfall to soil in place for making infiltration, runoff, and soil erosion measurements. Raindrops are formed by glass capillary tubes protruding through the base of the water supply tank. Each tube has chromel wire suspended in the capillary to reduce the rate of flow. The rainfall is delivered over a circular area 14.6 cm in diameter delimited laterally by a cylinder 15.24 cm long, driven vertically and flush with the soil surface. The soil surface is small and replications are easy to obtain. Air permeability measurements may be made before and after rainfall application. The equipment can be carried, set up, and operated by one man and offers a fast, economical means of evaluating the soil factor in runoff and soil erosion problems.

The kinetic energy of the rainfall simulator raindrops, after the fall of 1 meter, was computed to be equivalent to the kinetic energy of corresponding natural rainfall. The average size of the drops delivered was found to be 5.56 mm in diameter.

16 References

Alfaro, J. F. and Hachum, A. Y. 1977. A Simulation of Smooth-Variable Intensity Rainfall Patterns. Water Resources Bulletin 13(2): 349-364. Utah.

The objective of this paper is to introduce a technique for simulating continuously smooth-variable rainfall patterns, without considering the parameters of terminal velocity and drop size, which have been tested elsewhere (Chow and Harbaugh, 1965). This technique is based on the fundamental principal of a moving water head in a container. The proposed technique is general and capable of simulating any rainfall pattern. However, as the rainfall pattern gets more complicated, the equipment required for simulation becomes more involved. The proposed technique has been tested experimentally. A close agreement was found between the theoretical and experimental simulations. It is concluded that the proposed technique might be very useful in studying the infiltration and runoff processes under variable intensity rainfall, especially for simple convex patterns.

Both a picture and schematic diagram of the laboratory simulator are provided.

11 References

Amerman, C. R.; Hillel, D. I.; and Peterson, A. E. 1970. A Variable Intensity Sprinkling Infiltrometer. Soil Science Society of America Proceedings. 34:830-832. Wisconsin.

The Purdue sprinkling infiltrometer designed by Bertrand and Parr (1960) and modified by Dixon and Peterson (1964)-(1968) was modified by the writers to obtain low intensities. Without modifications for low intensities, one of three recommended nozzles can be used to obtain nominal intensities of 63.5, 82.6, or 118.9 mm/hr. Intensities much below the above could not be obtained with the same spray pattern and raindrop size simply by changing to different nozzles. The only feasable alternative seemed to be to intercept a part of the spray from one of the recommended nozzles.

The interception concept of a rotating disk unit with pie-slice openings was adopted. Four equally spaced openings were used in this development. A VM-113-30-DS Boston Ratiomotor (an electric motor and gear reducer) spun the disk unit at 58.3 rpm. This provided virtually steady precipitation at the ground surface about 3 m below the nozzle.

Since the disk openings were adjustable, sprinkling could be reduced from one-half the nozzle output to almost zero. In field operation, an intensity of 1 mm/hr was easily obtained. By visual observation of spray of impact craters on unprotected soil, the drop size did not change noticeably with intensity until very low intensities of the order 5 mm/hr. were obtained. At low intensity, the drop size was materially smaller.

The modified sprinkling infiltrometer, though somewhat harder to erect with the auxillary device for reduction of rain intensity, remains fully portable. The disk unit settings can be rapidly changed to allow variable intensity tests. Details with diagrams of the modifications are given.

14 References

Anderson, J. U.; Stewart, A. E.; and Gregory, P. C. 1968. A Portable Rainfall Simulator and Runoff Sampler. New Mexico State University Agricultural Experiment Station Research Report 143. 5p. New Mexico.

The device described here applies water to approximately a 4.88 x 6.10 m area with kinetic energy approximating that of natural rainfall, and it samples and records the rates of runoff in such a way that sediment production can also be measured accurately. The apparatus is patterned partly on that described by Meyer and McCune (1958). The major components consist of: 1) a 1500-gallon tank truck for transporting water and apparatus, 2) a demountable framework and moving spray assembly for applying water, and 3) a device for sampling and measuring the rate of runoff. Power is supplied by a 10-horsepower gasoline engine.

Water is applied continuously at four PSI from four nozzles for a rate of 10.16 cm per hour, or from eight nozzles for 20.32 cm per hour. Application rates can be lowered by cycling the machine on and off while maintaining the same nozzle pressure to simulate the relatively intense rainfall which is characteristic of many semiarid areas.

Two men can complete assembly and place this apparatus in operation in 1 to 1/2 hours, not including the half hour necessary to erect the plot edging. Several pictures are used to illustrate this rainfall simulator.

5 References

Barnett, A. P. and Dooley, A. E. 1972. Erosion Potential of Nature and Simulated Rainfall Compared. American Society of Agricultural Engineers. 15(6): 1112-1114. Georgia.

The rainulator designed by Meyers and McCune (1958) produces an average rainfall energy equal to 75 percent that of natural rain at 6.35 cm/hr. This would imply a downward bias in erosion data from tests using the rainfall simulator.

This hypothesis was tested on five plots 4.27 x 10.67 m of Cecil soil at Watkinsville, Georgia, during 1964-1967. Test plots were maintained in fallow, and erosion resulting from natural rain was recorded. During this time also, simulated rain tests at intensity of 6.35 cm per hour were also made at intervals on these plots. Nineteen natural storms and 35 simulated storms, ranging from 10 to 100 energy index(EI), were selected for comparisons.

In regression analysis the 5 percent confidence limits for the statistical parameter b, the rate of soil loss per unit of EI, was 0.222 ± 0.020 for natural rain and 0.204 ± 0.013 for simulated rain, indicating no significant soil loss per EI unit. Covariant analyses showed that the adjusted means to be significant at 5 percent but when the data were used to predict individual soil losses for a specific EI, the range of the predicted values overlapped, showing that if used for prediction purposes no real difference existed between the natural and simulated data reported here.

11 References

Befani, A. N.; Befani, N. F.; Goptchenko, E. D.; Ivanenko, A. G.; Odrova, T. V.; Terentyev, E. V. 1969. Experimental Study of Rainfall Runoff. International Association of Scientific Hydrology. Publication No. 84. p. 274-281. U.S.S.R.

Results of long-term experimental research on rainfall-runoff on plain and mountain watersheds situated in different regions of the USSR are discussed. Methods of active experimentation (sprinkling of plots and natural small drainage basins, slope submersion, pit digging and so on) are described. A review of the results obtained are outlined.

4 References

Bertrand, A. R. and Parr, J. F. 1961. Design and Operation of the Purdue Sprinkling Infiltrometer. Agricultural Research Service, USDA No. 723. 16p. Indiana.

This paper describes the design and operation of the Purdue Sprinkling Infiltrometer developed by Bertrand and Parr. This portable, sprinkling type infiltrometer uses three nozzles to give intensities of 6.35, 8.26 and 11.43 cm per hour with an average drop size of less than 1 mm. The plot size is 1.16 x 1.16 m. The nozzles met the criteria of distribution uniformity.

The instrument is composed of the following units: metal plot frames equipped with a runoff collection device and a calibration pan, circulating runoff accumulation system, automatic water stage recorder, telescoping aluminum tower for attaching the nozzle, pressure tank, pump and power unit, and water supply tank. Step by step operation procedures plus detailed diagrams are provided in this text for the unit's installation and operation.

6 References

Bertrand, A. R. and Sor, J. 1962. The Effects of Rainfall Intensity on Soil Structure and Migration of Colloidal Materials in Soils. Soil Science Society Proceedings. 26(3): 297-300. Indiana.

This paper presents the effects of rainfall on the clay content, specific surface, aggregate stability, and organic matter content of the several layers of three soil types. A description of the method of applying artificial rainfall and rainfall characteristics are described by Sor and Bertrand (1961). Thirty minutes of simulated rainfall at an intensity of 4.06 cm per hour was applied first. Then thirty minutes of rainfall with intensities of 7.11 and 10.16 cm per hour were applied. In general, the effects of the 7.11 and 10.16 cm per hour rainfall were of the same magnitude, while the effects of the 4.06 cm per hour rainfall were lower.

11 References

Beutner, E. L.; Gaebe, R. R.; Horton, R. E. 1940. Sprinkled Plot Runoff and Infiltration Experiments on Arizona Desert Soils. Transactions of the American Geophysical Union. 21:550. 30p. Arizona.

A sprinkler system, similar in most respects to the D-1 apparatus designed by the Soil Conservation Service in cooperation with the Bureau of Standards in Washington, was used in these experiments. The apparatus consists essentially of four stationary 1.5 "Mulsifyre" nozzles mounted on an overhead frame by which water may be applied at constant rates to a plot 1.83 m wide and 7.32 m long. With two nozzles in operation, water is applied at a rate slightly in excess of 7.62 cm/hr. and with four nozzles discharging, at a rate of 15.24 cm/hr. Satisfactory distribution of water is obtained with drop sizes comparable to actual rainfall, a study of the characteristics of drops indicating an effective size of about 1.6 mm.

The study plot is enclosed on three sides by 15.24 cm boundary plates which extend 10.16 cm below the surface. A strip 45.72 cm wide adjacent to the sides and upper end of the plot receives the same rain application as the plot to reduce any border effect. The entire sprinkling apparatus and study plot are enclosed with canvas curtains to provide a shield from winds.

Water is supplied from two carrying tanks mounted on a truck and trailer. It is first allowed to flow to a sump tank where it is maintained at a uniform level by a float valve. From there it is pumped to the applicator under a pressure of 5.5 lb. held constant by means of proper adjustment of pressure valves.

No References

Black, P. E. 1972. Hydrograph Responses to Geomorphic Model Watershed Characteristics and Precipitation Variables. Journal of Hydrology. 17(4): 309-329. New York.

The primary objective of this paper is to report the primary results of the Watershed Model Studies Project which was established to determine the effect of selected watershed characteristics on hydrograph parameters under a rainfall simulator. The rainfall simulator is a larger version of that used earlier (Black, 1970). It provides for complete time, intensity, and areal extent control over a test area 1.83 x 1.83 m in .61 x .61 m units, or modules, designed from specifications by Chow and Harbaugh (1965). The simulator consists of a Control System, including the main control panel which supplies power to the entire system; and the nine solenoids controlling delivery of distilled water to the modules, and the timing control panel which permits selection of storm duration and automatically controls the opening and closing of the solenoids.

Intensities ranged from 39.62 cm/hour to 118.87 cm/hour.

37 References

Blackburn, W. H. 1975. Factors Influencing Infiltration and Sediment Production of Semiarid Rangelands in Nevada. Water Resources Research 11(6): 929-937. Nevada.

The infiltrometer and methods of application are described by Blackburn et al (1974). An application rate of 7.62 cm per hour for one-half hour was applied. Two types of plots were used, .91 x .91 m and variable.

27 References

Blackburn, W. H. 1973. Infiltration Rate and Sediment Production of Selected Plant Communities and Soils in Five Rangelands in Nevada. University of Nevada. 99p. Nevada.

An infiltrometer was designed and built after one described by Chow and Harbaugh (1965) but modified for field use for this project. The infiltrometer was built on a U. S. Army surplus two wheel trailer. The water supply is a 1135.62 liter tank where the water is pumped to the elevated 189.27 liter tank for gravity flow through filters and flow meters to the water chambers. Chambers are suspended from adjustable arms. Power source is a large 12 volt battery. Runoff plots are of two types, regular .91 x .91 m and variable.

Water chambers are constructed of 1.22 x 1.22 m, 6.35 mm thick plexiglass sheets bolted to angle aluminum. Raindrop producing tubes are 23 gage stainless steel, 19.05 mm long with .48 mm inside diameter. Tubes are placed on 25.40 mm spacings. Adjustable guy wires are used to level the water chambers and these chambers are 2.13 m above the soil surface. At this distance simulated drops reach about 72 percent of maximum falling velocity. Water was applied at two rates, 3.81 cm per hour for one hour and 7.62 cm per hour for one-half hour.

122 References

Blackburn, W. H. 1973. Simulated Rainfall Studies of Selected Plant Communities and Soils in Five Rangeland Watersheds of Nevada.

The rainfall simulator used in this study is the same as used in Blackburn (1973). Water was applied to the plots at two rates, 3.81 cm/hr for one hour and 7.62 cm/hr for one-half hour.

121 References

Blackburn, W. H.; Meeuwig, R. O. and Skau, C. M. 1974. A Mobile Infiltrometer for Use on Rangeland. Journal of Range Management. 27(4): 322-323. Nevada.

This paper describes a drip type infiltrometer used by Blackburn (1973) to measure infiltration rates and sediment production of arid and semiarid rangelands in Nevada.

The infiltrometer is mounted on a two wheel trailer. Water is pumped from the 1135.62 liter tank to the elevated 208.20 liter barrel and flows by gravity through filters and flowmeters to the raindrop-producing modules. Modules are suspended 2.13 m above the soil surface on adjustable arms. Simulated raindrops reach about 70% of their terminal velocity at 2.13 m (Todd, 1970).

The raindrop-producing module is similar to the one originally described by Chow and Harbaugh (1965) and to modified versions of it described by Timko and Skau (1967) and Meeuwig (1971). The module consists of two 1.22 x 1.22 m sheets of 6.35 mm plexiglass spaced 12.70 mm apart, sealed with caulking compound, and bolted to angle aluminum. Each module has 2,209 tubes at 2.54 cm spacing that project 6.35 mm both above and below the lower plexiglass sheet. These tubes are 23 gauge stainless steel, 19.05 mm long and have an inside diameter of .48 mm. Epoxy cement holds the tubes in place. Rainfall intensities of about .508 cm/hr to about 8.38 cm/hr can be simulated with the Manostat flowmeter used. Wind shields similar to those used by Dortignac (1951) are usually necessary to avoid excessive drift of simulated raindrops. A standard plot frame of .91 x .91 m or a variable one is used.

Pictures of the simulator plus directions for operation are also given.

6 References

Bovey, R. W. and Diaz-Colon, J. D. 1969. Effect of Simulated Rainfall on Herbicide Performance. Weed Science. 17(2): 154-157. Puerto Rico.

Studies were conducted to determine the effect of simulated rainfall on the phytotoxicity of several herbicides. After herbicides were applied, washing treatments in four experiments were provided with a spray nozzle to deliver approximately 2.54 cm simulated rainfall in 1 minute. Simulated rainfall in the fifth experiment was provided by calibrating an automated greenhouse sprinkler to deliver 1.27 cm rainfall in approximately 60 minutes. This was applied for 5, 30, amd 60 minutes to approximate .107, .635, and 1.27 cm rainfall, respectively.

4 References

Brazil, L. E. 1976. A Water Quality Model of Overland Flow. M. S. Thesis. Colorado State University. 141p. Colorado.

The objectives of this study were to develop and test a theoretical water quality model and find a means for estimating its parameters. The experimental runs were made on the Colorado State University Rainfall Runoff Experimental Facility. (Dickenson, Holland, Smith, 1967.)

The simulated rainfall was generated by 277 sprinklers, each located on top of a 3.05 m vertical pipe. Water was supplied to the sprinkler risers by aluminum lines running in parallel across the watershed. The aluminum feeder lines were spaced approximately 5.33 m apart and each line had about 20 risers, each spaced 3.05 m apart. Various intensities were created by operating different combinations of sprinklers. The combinations were controlled by electric solenoid valves located on the side of the facility. When all sprinklers were running simultaneously, approximately 108 mm/hr of rainfall input was being generated on the half acre plot. Use of fewer risers would create intensities of 58, 28, and 13 millimeters per hour.

31 References

Brockman, F. E.; Duke, W. B.; and Hunt, J. F. 1975. A Rainfall Simulator for Pesticide Leaching Studies. <u>Weed Science</u>. 23(6): 533-535. New York.

The construction and operation of an apparatus for applying rainfall to soil columns being used for pesticide leaching studies is described. The apparatus will uniformly deliver water to many soil columns over a wide range of natural rainfall rates. It consists of three components; the water delivery system, the water control system, and the drive mechanism.

The rate of water application to the columns is controlled by the size of the nozzle orifice, the height of the nozzle above the columns, and the water pressure. Using flat spray nozzles, simulated rainfall can be applied at rates of 1.7 to 28.2 cm/hr with a maximum coefficient of variability of 3.8%. To obtain rates less than 1.0 cm/hr it is necessary to use the valve-timer mechanism.

Nozzle spray patterns are not uniform. Therefore, it is necessary to place the tops of all columns on a circle around whose center the nozzle rotates. This is accomplished by lowering the nozzle boom to within a short distance of the column tops, taping a broom straw to the nozzle, and as the nozzle rotates, adjusting the position of the columns so that the straw just brushes the outside edge of each. The straw is then removed and the boom raised to the desired height above the column.

In simulating field conditions, the duration of water application and the time period between applications should be controlled to correspond to natural phenomena.

6 References

Bubenzer, G. D. and Jones, B. A., Jr. 1971. Drop Size and Impact Velocity Effects on the Detachment of Soils Under Simulated Rainfall. Transactions of the American Society of Agricultural Engineers. 14(4):625-628. Illinois.

The objective of this research was to investigate the importance of two basic parameters (rainfall mass and impact velocity) on the detachment and splash of soils. A corrugated metal tower with an attached work area was constructed to provide environmental control for the splash study. The tower portion of the structure had an eave height of 9.75 m and a diameter of 3.66 m. The height of the simulator over the plot was controlled by a chain hoist. Water was supplied from an underground storage tank.

Three plexiglass modules, each 40.64 cm wide, 121.92 cm long, and 2.54 cm deep were constructed for each of the three drop sizes used. Twenty-seven gauge needles, 20 gauge needles and 9 gauge milled stainless steel tubing were used to produce 2.2, 3.2, and 4.9 mm drops, respectively.

Before each run, the modules were adjusted to the desired height and the head over the modules was adjusted to give the desired rate of application. A minimum of 30 minutes was allowed for the rainfall to reach equilibrium. The majority of the test runs lasted 10 minutes. Runs of longer duration were necessary for the smaller drops in order to obtain the high energy level.

The mean splash rate of soils exposed to rainfall of a nearly constant kinetic energy level and impact velocity was influenced by drop size at the lower energy levels. The smaller drops produced significantly less splash than the larger ones, even though the kinetic energy, total rainfall mass and impact velocity were almost constant. As the energy level increased, the influence of drop size decreased.

12 References

Buckhouse, J. C. and Gifford, G. F. 1976. Sediment Production and Infiltration Rates as Affected by Grazing and Debris Burning on Chained and Seeded Pinyon-Juniper. Jour. of Range Management. 29(1):83-85. Utah.

Sediment Production and Infiltration rates were measured in conjunction with an analysis of burning and grazing treatments in a chained pinyon-juniper study in southeastern Utah.

A Rocky Mountain infiltrometer (Dortignac, 1951) was used to generate runoff from small plots, each plot being 0.23 m^2 in size. All plots were pre-wet prior to application of simulated rainfall in order to eliminate confounding effects of antecedent moisture. Artificial rainfall was thus applied to the plots at a rate of approximately 7 cm per hour for 28 minutes. Both runoff and "rainfall" were collected initially, after 3 minutes, and subsequently at 5 minute intervals during the rainfall period.

5 References

Busby, F. E., Jr. 1977. Effects of Livestock Grazing on Infiltration and Erosion Rates Measured on Chained and Unchained Pinyon-Juniper Sites in Southeastern Utah. Ph.D. Thesis. Utah State University. 130p. Utah.

The runoff and erosion for this study were artificially induced from small plots by simulating rainfall with the Rocky Mountain Infiltrometer (Dortignac, 1951). Artificial rainfall was applied by the infiltrometer at a rate of 7.5-12.5 cm/hr. The raindrops produced by this simulator tend to be larger than those of actual thunderstorms, but have lower impact velocities.

Three infiltrometer plot frames were used for each infiltration test during this study. These plots were approximately 0.24 m^2 in size (0.77 m x 0.31 m). The Rocky Mountain infiltrometer sprinkles an area approximately 4 m in diameter; therefore, a control of lateral flow from the plots was provided when three plots were used. This alteration allowed increased efficiency of water use (few water sources existed near the study area).

63 References

Chow, V. T. and Harbaugh. 1965. Raindrop Production for Laboratory Watershed Experimentation. Journal Geophysical Research. 70p. 6111-6119.

A technically efficient method for producing raindrops is presented. This approach is based upon broad basic requirements to be adopted in the systems engineering for an experimental investigation on watershed hydraulics. Modular construction of the raindrop-producing device is adopted, allowing variable time distribution and areal coverage of rainfall intensities from 1.85 to 33.02 cm/hr, with average velocity from 0.01 to 0.22 m/sec. on a plot up to 12.19 x 12.19 m. Theoretical and photographic comparisons are made for the formation and velocity determination of 3.2 mm drops produced through polyethylene tubes of 0.58 mm ID. Procedures and formulas are given for making such determinations under other conditions. The proposed rainfall producer provides fast response to on-off commands and produces in the laboratory controllable simulated storms of flexible time and areal distribution patterns.

13 References

Cluff, C. B. and Boyer, D. G. 1971. The Use of a Realistic Rainfall Simulator to Determine Relative Infiltration Rates of Contributing Watersheds to the Lower Gila Below Painted Rock Dam. Water Resources Center, University of Arizona. 19p. Arizona.

This report contains a comparison of the rotadisk rainulator with natural rainfall. In both erosion studies and infiltration studies, the failure to adequately duplicate drop size distribution and the terminal velocity of natural rainfall can result in gross errors. If there are no exposed surfaces, such as in a dense grass cover, drop size distribution and kinetic energy of the simulator are not important. Under this condition, the important factors are the intensity and uniformity of application over the plot. According to a survey by Meyer (1965), the rainfall parameters which are important in both the erosion of the soil and the infiltration rate on exposed surfaces include (A) kinetic energy ($1/2\ MV^2$), (B) momentum (MV), (C) kinetic energy per unit of drop-impact area ($1/2\ MV\ /A_d$), and (D) interactions of these variables with rainfall intensity.

The rotadisk rainulator provides essentially the same kinetic energy and momentum per unit of rainfall as natural rainfall of 5.08 cm/hr. For intensities less than 5.08 cm/hr it gives slightly higher kinetic energy, and for intensities higher than 5.08 cm/hr it gives slightly lower kinetic energy than natural rainfall as reported by Laws and Parsons (1943). For all intensities above approximately 2.54 cm/hr the Rotadisk Rainulator comes much closer to duplicating natural rainfall than has been achieved by other types of rainfall simulators.

10 References

Cluff, C. B.; Evans, D. D.; and Morse, J. G. 1972. Development of a Mathematical Model of Infiltration Which Includes the Effects of Raindrop Impact. University of Arizona. 25p. Arizona.

In both field and laboratory studies the rota-disk rainfall simulator (Morin, Cluff, and Powers, 1970) was utilized. This device provides impact velocities and drop size distributions closely approximating natural rainfall. Momentum and kinetic energy of drops are also similar to natural rainfall, and the intensity can be varied over a wide range.

Over a period of several years, rainfall simulators runs were made on experimental plots 1.50 x 1.50 meters on about a one percent slope at Page Ranch, northeast of Tucson, Arizona. The amount of grass cover varied from zero to almost full covered. These tests shower a 10-fold decrease in infiltration when the protective vegetation was removed. To calibrate the rainfall simulator, plastic was placed over a plot and 100% of the input rainfall collected as runoff. For both the calibration and infiltration runs, the simulator was leveled and operated at the same pressure and height above the plot. On a few of the runs errors in estimating the input rainfall may have been as much as 5 to 10 percent. Fluctuations in the portable power source, variation in pressure, and difficulties with the nozzle accounted for most of these problems. The average value for the input rainfall for the field infiltrometer runs was 4.27 cm/hr.

In the laboratory, two infiltrometer runs were conducted using rainfall intensities of both 3.68 cm/hr and 1.47 cm/hr on plots of 9 cm x 25 cm. The order of application of the intensities was reversed from one run to the next. The purpose of these two runs was to observe the interaction of varied intensities on infiltration rates.

10 References

Costin, A. B. and Gilmour, D. A. 1969. Portable Rainfall Simulator and Plot Unit for Use in Field Studies of Infiltration, Runoff and Erosion. Journal of Applied Ecology. 7(1): 193-200. Queensland, Australia.

Equipment is described for determining infiltration, surface runoff, and soil- and nutrient-erosion characteristics of field sites. The equipment is robust and portable, and can be rapidly assembled, operated and dismantled by one person.

The 3.05 x 1.83 m plots are enclosed by a mild-steel top, jointed side-sections, and an angle-iron collecting drain with an outlet leading to a container of suitable size. Simulated rainfall is supplied to the plot from drums of water by means of a mobile engine driven centrifugal pump fitted with a by-pass valve. The rain is directed on to the plot with a hand-operated boom and nozzle from which the amount and intensity of the rainfall are controlled.

This equipment delivers simulated rain with median drop size of 1.3 mm at an intensity of 320 points/hr and a terminal velocity of 7.92m/sec. These values are generally similar to those found for comparable natural storms.

Some field applications are described.

14 References

Craddock, G. W. and Pearse, C. K. 1938. Surface Runoff and Erosion on Granitic Mountain Soils of Idaho as Influenced by Range Cover, Soil Disturbance, Slope, and Precipitation Intensity. United States Department of Agriculture Circular No. 482. 24p. Idaho.

For this study, a special apparatus was developed for producing artificial rainstorms of the desired amount and intensity and for measuring the resulting runoff and erosion. The major parts of this apparatus included a pump unit for supplying water under pressure from the nearest creek or lake or from a portable storage tank; a sprinkler system capable of producing artificial storms over areas approximately 4.57 x 15.24 m; sheet metal equipment for delimiting a plot 2.01 x 10.06 m and for collecting runoff and eroded material, and devices for measuring and recording the amount and rate of rainfall and runoff. This apparatus combines the artificial-rainfall features of the instrumentation used by Lowdermilk (1930) and Duley and Ackerman (1934) with field-plot methods used by Lowdermilk (1934), Meginnis (1935), and many other workers, but differs from all these in that it is completely portable.

Between 4.45 and 4.70 cm of precipitation was applied in 60 minutes to simulate a moderately intense storm on one-half the plots and in 30 minutes to approximate high intensity rainfall on the others.

The appendix gives a detailed description of the portable rain maker and erosion-study apparatus.

16 References

Dangler, E. W. and El-Swaify, S. A. 1976. Erosion of Selected Hawaii Soils by Simulated Rainfall. Soil Science Society of America Proceedings. 40(5): 769-773. Hawaii.

Erodibilities were determined for ten soils representing five soil orders on the islands of Oahu and Hawaii. Simulated rainfall was applied at an intensity of approximately 6.35 cm/hr for 120 minutes, using a rainfall simulator similar to that described by Meyer and McCune (1958). Test plot areas were 83.6 m^2 (22.9 x 3.66 m) and/or 39.0 m^2 (10.7 x 3.66 m). Two successive rainstorms were storms used of the same duration and intensity. The weighted erodibility of a soil at a given location was in general, inversely related to the amounts of natural precipitation at that location.

12 References.

Dangler, E. W.; El-Swaify, S. A.; Ahuja, L. R.; and Barnett, A. P. 1976. Erodibility of Selected Hawaii Soils by Rainfall Simulation. Agricultural Research Service Publication, V1976, NW(35):1-113. Hawaii.

The rainulator unit employed for the study was from the Piedmont Conservation Research Center, ARS, USDS, Watkinsville, Ga. It consists of a portable frame on which carriages bearing spray nozzles are driven back and forth during operation across an experimental plot. Using appropriate controls, nozzles are allowed to spray at an intensity of 3.18, 6.35, or 12.70 cm/hr. The medium intensity was used throughout this study. As discussed by Meyer and McCune (1958), the spray produced approximate natural rain in drop size distribution and kinetic energy at impact. A minor drawback is that each bank of nozzles operates intermittently so that the calculated energy of impact for a given quantity of applied rainfall represents average rather than actual energy. Moreover, the natural rainfall being simulated by this unit may not be realistic for tropical rainstorms, such as prevail in Hawaii, as for regions in which it was designed. For example, in a 6.35 cm/hr "rain" a bank of nozzles sprays only 20 percent of the time during the reciprocating carriage movement operative on the 10 to 11 second cycle.

Some operating statistics include a waterline pressure of 40 lb/sq in. reduced to 6 lb/sq in. at each nozzle, producing a 15.4 liter/min application through each nozzle. Long and short plots contained 48 and 24 nozzles per 900 ft^2 or 420 ft^2, respectively. Nozzle heights were 2.44 m above the plot surface. The average kinetic energy of impact is 800 feet-tons/acre/in. in storms of 6.35 cm/hr.

51 References

Disrud, L. A. and Krauss, R. K. 1971. Examining the Process of Soil Detachment from Clods Exposed to Wind-Driven Simulated Rainfall. Transactions of the American Society of Agricultural Engineers. 14(1):90-92. Kansas.

One thousand grams of clod samples were exposed for 30 minutes to simulated wind-rainstorms in a wind tunnel-raintower facility. Rainstorms were simulated in the facility by spray nozzles located 10.4 m above the wind tunnel floor. Drops falling this distance in still air will attain at least 95 percent of their terminal velocity, and rainfall intensity can be controlled by adjusting the number and size of spray nozzles used. Intensities of 1.93 to 3.89 cm/hr were used.

Rainfall-energy values were determined for various combinations of windspeed, nozzle number and size, and location of tests on the floor of the raintower. Drop size distributions were determined by the flour method. A prediction equation developed in a previous study was used to calculate resultant velocities of drops in the various drop-size groups. To measure rainfall intensities in wind, shallow metal trays containing a water-absorbing polyurethane foam material of known area were exposed for a definite time period; they were weighted before and after exposure. Kinetic energy values were determined by methods developed by Wischmeier and Smith.

10 References

Doran, R. L. and Andersen, R. N. 1975. Effects of Simulated Rainfall on Bentazon Activity. Weed Science. 23(2):105-109. Minnesota.

In these field studies simulated rainfall was used to determine bentazon's activity on velvetleaf and cocklebur. The simulated rainfall was applied by watering with a sprinkling can. The can was held so that water fell on a 2.3 cm band centered on the row. The plants were sprinkled by moving the sprinkler can back and forth along the row several times. Then sprinkling was stopped so that water could soak into the soil. Sprinkling continued periodically until a 2.4 cm simulated rainfall had been applied during a period of 0.5 hr. An individual plot consisted of one 1.8 m row of either weed species.

5 References

Dortignac, E. J. 1951. Design and Operation of Rocky Mountain Infiltrometer. Rocky Mountain Forest and Range Expt. Sta., Station Paper No. 5, 68p.

The complete Rocky Mountain infiltrometer consists of the following major items:

1. Power Pump.
2. 1-1/2 ton truck with mounted 1,514-1,892 liter capacity storage tank.
3. Portable metal plot frames, rainfall troughs, and rain applicators.
4. Circulating system.
5. Calibration equipment.
6. Windbreaker tents and canvas plot covers.
7. Collector and sediment cans, graduates, and trays.

A complete list of items is contained in the appendix. A general description and photograph of each major item is given in the text. Specific details and plans for construction are given in the appendix.

The rainfall applicator uses three type-F nozzles that are attached to a 19.05 mm pipeline system that is permanently mounted on an angle iron frame.

Rainfall intensities from 6.35 to 13.97 cm per hour are available for the .76 square meter plots. The simulated rain falls 2.13 m. Data of test runs are given.

22 References

Dortignac, E. J. and Love, L. D. 1961. Infiltration Studies on Ponderosa Pine Ranges of Colorado. Rocky Mountain Forest and Range Expt. Sta. Paper No. 59, 34p. Colorado.

The Rocky Mountain infiltrometer (Dortignac, 1951) was used to measure all infiltration rates. With this system, artificial rain is applied to and area of about 12.19 square meters on and surrounding the .76 square meter infiltrometer plot. Wetting a large area surrounding the plot simulated conditions during natural rainfall and tended to reduce subsurface lateral movement of water through the soil. Intensities of applied rainfall varied slightly during the 50 minute test periods, although relatively constant water pressures were maintained. Likewise, average rainfall rates between tests varied from 10.16 to 12.70 cm an hour, but averaged 11.43 cm.

16 References

Epstein, E. and Grant, W. J. 1966. Design Construction and Calibration of a Laborabory Rainfall Simulator. Technical Bulletin 22, 9p. Maine.

The rainfall simulator at the University of Maine was designed for the study of soil characteristics as related to soil erodibility. The applicator, constructed from design plans developed at the Purdue University workshop in 1958, is located at the top of a 9.14 meter conventional silo. This arrangement provides a 7.62 meter height of fall and convenient working space.

The applicator is 137.16 cm in diameter and consists of eight wedge-shaped segments. This unit rotates at 1 rpm. The applicator head is supported from the floor, as its weight with water is in excess of 136.08 kg. Two different drop formers are used. To produce a 5.1 mm drop, a drop former was made of short lengths of stainless steel tubing in a graded series. Water enters the small diameter tubing and the large diameter tubing provides the desired drop size. To produce drops of 3.2 mm diameter a 24 gauge stainless steel tubing is being used.

To minimize a drop furrow effect on the surface of the soil sample, each wedge-shaped section of the applicator has a different drop former arrangement. Four 30.48 x 30.48 cm soil pans serve as the plots.

11 References

Epstein, E. and Grant, W. J. 1967. Soil Losses and Crust Formation as Related to Some Soil Physical Properties. Soil Science Society of America Proceedings. 31(4): 547-550. Maine.

Soil loss curves of six soil types were obtained using a rainfall simulator. The rain simulator used in this study was described by Epstein and Grant (1966). Simulated rain of 3.2 mm drop size was applied for 90 minutes at a rate of 63.5 mm/hr to a plot 30.5 cm square.

Under field conditions, splash material is subject to displacement and transport downslope. With laboratory rainfall simulators, splash material is frequently not returned and hence does not become a component of the runoff water. Soil in raindrop splash increased with drop size, drop velocity, and rainfall intensity. The objective of this study was to evaluate some of factors which may explain the different erodibility characteristics of soils.

12 References

Farmer, E. E. 1973. Relative Detachability of Soil Particles by Simulated Rainfall. Soil Science Society of America Proceedings 37(4): 629-633. Utah.

Disturbed surface soil masses of two coarse-grained granitic soils and a single fine-textured clay soil were subjected to simulated rainfall on a 46 x 122 cm plot.

The rainfall simulator used was described by Packer (1957). Two levels of constant rainfall intensity were used, approximately 7.5 cm/hr or 150 cm/hr. The range of drop sizes for both rainfall intensities was from less than 0.5 mm to slightly over 5 mm. At a rainfall intensity of 16 cm/hr, the average drop size was 1.87 mm and the D_{50} drop size was 3.55 mm. (The D_{50} drop size is that size at which 50% of the water comes in drop diameters smaller than the D_{50}). At a rainfall intensity of 7.5 cm/hr, the average drop size was 1.50 mm; the D_{50} size was 3.14 mm. Raindrop sizes were estimated by the flour pan method. Fall distance of the drops was 6.4 m. There were no wind effects. Raindrop fall velocities were estimated from Law's data. Kinetic energy of rainfall at 16 cm/hr was approximately 2.65×10^5 ergs/cm^2 per cm and at 7.5 cm/hr, 2.44×10^5 ergs/cm^2 per cm. These kinetic energy figures are about 92 and 96%, respectively, of the kinetic energy expected from equivalent intensities during natural rainstorms.

In this study, the effect of rainfall intensity on soil particle detachability could be detected, but the effect was not as large as expected, nor was it linear.

12 References

Farmer, E. E. and Van Haveren, B. P. 1971. Soil Erosion by Overland Flow and Raindrop Splash on Three Mountain Soils. U.S.D.A. Forest Service, Research Paper INT-100. 14p. Utah.

This study used a laboratory rainfall simulator described by Packer (1957), except that the F-type nozzles were raised to 3.66 m above the concrete floor and the hole in the end disc of each nozzle was reduced from 3.18 to 2.64 mm. These modifications greatly increased the fall distance of the drops and reduced the average drop size. The range of drop sizes for both the 7.62 and 17.78 cm per hour intensities varied from less than 0.5 mm. to slightly more than 5.0 mm. At 17.78 cm per hour, the average drop size was 1.87. For the 7.62 cm per-hour intensity, the average drop size was 1.91 mm. The plot was 122.24 by 46.04 cm.

12 References

Gabriels, D. and De Boodt, M. 1975. A Rainfall Simulator for Soil Erosion Studies in the Laboratory, Pedologie. XXV, 2:80-86. Belgium.

This paper describes the design principles of the rainfall simulator constructed at the Laboratory of Soil Physics at the State University of Ghent, Belgium. A circular iron water tank is suspended from a frame assembly (four corner posts reinforced by horizontal and diagonal stays). Cupper capillary tubes inserted through the bottom of the tank allow for the raindrops to pass through. Raindrop sizes can be varied by changing the tip diameter of the capillary tubes. The drop diameter is a function of the circumference of the base of the capillary tube, the surface tension and of the waterheight above the capillary tube.

Rains of various intensities (4.7, and 64.5 mm/hr) can be controlled by changing the number of dripping capillaries per unit area and their sizes, as well as adjusting the hydrostatic head above the drop formers. Small intensities can be obtained by plugging 50% or 75% of the total number of drop formers (50% and 25% efficiency).

The applicator tank, placed at a height of 2.75 m above the soil, is arbitrarily chosen to turn at one revolution per minute to attain the desired angular distribution with the horizontal component of drop velocity being minimized. The first experiments have shown that the drops had a uniformly spirally distribution, but after each revolution the drop hits the same spot on the soil surface. To avoid this, two electric fans are placed on opposite sides of the applicator. Hence, while falling the drops are subjected to a certain amount of deflection from the perpendicular due to air currents. This deflection is sufficient to produce a randomized raindrop distribution over the soil surface especially as the two electric fans are blowing horizontally and constantly changing their angle of impact over almost 90° with the falling drops.

6 References

Gifford, G. F. and Hawkins, R. H. 1976. Preliminary draft. Hydrologic Impact of Grazing - A Critical Review. For publication as a journal paper of the Utah Agricultural Experiment Station, Logan, Utah.

This paper raised several questions involving infiltrometers. Infiltrometers are one of the few instruments available to make on-site measurements of hydrologic conditions. Nonetheless, there are limitations inherent in their usage which should be understood, and if possible, relaxed for wider application.

Although the most useful data to date has been collected from sprinkling infiltrometers, their use is time consuming and labor demanding. Ring infiltrometers are simpler, quicker, and cheaper, although less realistic and less of an areally integrated sample. Thus, for the practicing land manager, relationships are needed between results from sprinkling infiltrometers and ring infiltrometers, so that the convenience of the latter can be combined with the reality of the former. Such a statement assumes a uniformity between sprinkling infiltrometers, and that they are indeed a valid representation of the field rainfall infiltration process. This consideration also needs to be investigated and rectified.

Information is certainly needed on the areal distribution of infiltration rates across watersheds, the variation within small distances, the consequences of using averages, etc. Similarly, lacking other techniques, it will be necessary to relate infiltration estimates such as soil groupings and runoff curve numbers. Such technology is currently in its infancy.

31 References

Gifford, G. F. and Tew, R. K. 1969. Evaluating Rangeland Water Quality with Small Plot Infiltrometer. <u>Journal of Soil and Water Conservation</u>. 24(2): 65-76. Utah.

Disturbing the soil on western rangelands alters the chemical qualities of water, and small plot infiltrometers appear to be one means of measuring the chemical changes. Use of small plot infiltrometers enables collection and analysis of both applied and runoff water. In addition, several plots can be studied each day with a minimum of water. The Rocky Mountain infiltrometer Dortignac (1951) was used.

The infiltrometer was used to apply simulated high intensity (6.86 cm per hour or greater) rainfall on each plot. Eight infiltrometer runs were used on each 30-acre area. Runoff was collected from a .76 square meter area within each infiltrometer plot frame. The length of infiltrometer runs varied from 14 to 26 minutes.

This study concluded that small plot infiltrometers appear to be suitable for detecting changes in the quality of runoff water from western rangelands.

2 References

Hall, M. J. 1970. A Critique of Methods of Simulating Rainfall, Water Resources Research. 6(4): 1104-1114. London, England.

Observations of drop size distributions in natural rainfall have shown that the range of drop sizes increases with increasing rainfall intensity. If a network of nozzles is used to generate artificial rainfall, an increase in working pressure increases the average intensity but decreases the range of drop sizes within the spray. This property has hindered the development of the rainfall simulator more than any other single factor. Alternative methods of simulating rainfall which depend upon individual drop forming elements such as hypodermic needles for example, are capable of producing sprays with uniform drop sizes only. Such methods have been employed successfully in generating storm patterns involving both temporal and spatial variations in intensity for laboratory catchment studies. A general purpose rainfall simulator, combining control of application rates in both space and time with the reproduction of the drop size distributions and velocities of fall of drop observed in nature, has yet to be developed.

43 References

Harris, A. R. 1972. Infiltration Rate as Affected by Soil Freezing Under Three Cover Types. Soil Science Society of America Proceedings. 36(3): 489-492. Wisconsin.

Infiltration rate in a frozen Fayette silt loam soil under contiguous areas of natural deciduous forest, 25-year-old coniferous plantation, and 6-year-old abandoned field vegetation was measured using tin can infiltrometers.

Ring infiltrometers made from No. 10 tin cans (15.7 cm x 17.8 cm) were installed before the soil froze. Six cans, one for each run to be made, were installed in each subplot. Each run required 36 infiltrometers (two on each of six plots in each of the three cover types). The six runs required a total of 216 cans, since each was used only once. They were installed at a depth of 12 cm with 5.8 cm protruding to accommodate a head of water and stock water tank float. The floats were used to maintain constant and equal heads.

A 3:1 water-ethylene glycol solution was fed into the infiltrometers with a flexible hose attached to a calibrated reservoir. The solution did not cause noticeable thawing of the soil during a run but subsequent thawing was evident.

12 References

Hermsmeier, L. F., Meyer, L. D., Barnett, A. P. and Young, R. A. 1963. Construction and Operation of a 16-Unit Rainulator. ARS 41-62, Agricultural Research Service, USDA. 136 pp.

Based on studies on natural rainfall and many previous rainfall simulators, the rainulator was designed with the following characteristics:

1. Is completely portable.
2. Can cover plots of various sizes.
3. Can cover several plots simultaneously.
4. Applies drop-size distribution near that of natural rainfall.
5. Provides drop velocity of fall near that of natural rainfall.
6. Produces kinetic energy at impact approximately 80% that of corresponding natural rainfall.
7. Applies intensities in the range of storms that produce medium to high rates of runoff and erosion (3.18, 6.35, and 12.70 cm/hr.).
8. Uses standard runoff and soil loss measuring equipment.
9. Operates satisfactorily in wind velocities of less than 15 mph.
10. Can reproduce specific simulated storms.

The rainulator is designed for rectangular plots that are 4.27 m or less in width and have center to center distances of 5.49 m. The first unit of the rainulator covers an effective plot length of 4.57 m up the slope. Each additional unit covers 6.10 m farther up the slope.

The unit consists basically of a series of frames that support the carriages on which are mounted the nozzles. A small gasoline engine supplies the energy that drives the carriage in a controlled speed reciprocating motion. Water is supplied to the nozzles through irrigation pipe, plastic pipe, rubber hose, and appropriate fittings. The spraying from the nozzles is controlled by electical solenoid valves that are synchronized with the carriage cycles by means of switches and relays.

Complete instructions with a parts list are given for the construction and operation of this rainulator, along with detailed drawings.

No References

Holland, M. E. 1969. Design and Testing of Rainfall System. Colorado State University Experimental Rainfall-Runoff Facility. 82p. Colorado.

This facility uses a grid system for rainfall simulation. It is based on a sprinkler nozzle located on a riser above the aluminum supply main. The riser section is about 3.05 m high. The 1905 mm riser is guyed to the adjacent risers by a wire, which is anchored at the ends of the aluminum supply line.

The sprinkler head is mounted at the top of the risers. A 2.13 m section 1905 mm steel pipe joins the sprinkler to a tire pressure tap. The pressure tap allows a rapid check of pressures at a number of risers in a very short time, using a pressure gage that has been equipped to fit the tire pressure tap. The pressure regulator maintains the pressure for the sprinkler at a constant value so all will have the same pressure. The pressure is currently set at 28 psi. A hydraulic valve below the pressure regulator turns the sprinkler on and off. Each nozzle is fitted with a control valve, and a series of valves is connected to one pressure manifold to provide simultaneous operation of a set of sprinklers.

A small plastic pipe joins a set of risers to the pressure manifold. The supple to the pressure manifolds is controlled by electric control valves that are connected a switching panel in the instrument trailer. There are four different sets of sprinklers in the system. The intensities available are 1.27 cm/hr, 2.54 cm/hr, and 5.08 cm/hr. A variety of intensities can be obtained by simultaneous operation of the different sprinklers.

Many diagrams, charts and graphs are used to more fully explain this system.

8 References

Jager, D. J. 1972. The Influences of Cultural Practices and Seeded Species on Overland Flow and Sediment Production from the Big Sage Cover Type in East Gate Basin. University of Nevada. 182p. Nevada

This research program used an infiltrometer for its rainfall. This portable infiltrometer employed 14 vertical F-type nozzles (Dortignac, 1951) and was capable of applying 9.40 cm per hour when the water pressure was maintained at 22 pounds per square inch. A wind frame surrounded the runoff plot and infiltrometer during the tests to provide protection from winds which, if allowed to pass over the infiltrometer, would reduce the uniformity of raindrop application. The approximate size of the plots was 16.76 square meter.

33 References

Kelling, K. A. and Peterson, A. E. 1975. Urban Lawn Infiltration Rates and Fertilizer Runoff Losses Under Simulated Rainfall. Soil Science Society of America Proceedings. 39(2): 348-352. Wisconsin.

Infiltration runoff measurements were made on nine urban lawns using a sprinkling infiltrometer in conjunction with the application of a complete fertilizer at three rates. A modified spray infiltrometer developed by Dixon and Peterson (1964) was used for a 90 minute application at the rate of 12 cm/hour.

25 References

Kilinc, M. and Richardson, E. V. 1973. Mechanics of Soil Erosion from Overland Flow Generated by Simulated Rainfall. Hydrology Papers, Colorado State University. 54p. Colorado.

The mechanics of soil erosion from overland flow generated by simulated rainfall are studied experimentally and analytically. The experiments were conducted in a 1.22 m deep, 1.52 m wide, and 4.88 m long flume. Twenty-four runs were made over bare sandy soil, using six different slopes (5.7 to 40 percent) and four different rainfall intensities (3.18 cm to 11.68 cm per hour). In this research, the discharge, velocity, depth of flow, and rate of sedimentation were measured for each slope and intensity of rainfall.

The simulator consisted of commercial sprinklers on 3.05 m risers, placed 3.05 m apart along the sides of the flume. The sprinkler head was mounted on top of the riser. A 2.13 m section of 1.91 cm steel pipe joined the sprinkler to the tire pressure tap. Each nozzle was fitted with a control valve, and a series of valves were connected to one pressure manifold to provide simultaneous operation of a set of sprinklers.

Four independent control valves were fixed to manipulate the pressure system of the sprinkler riser on the upstream part of the flume so that rainfall production for this experiment could be operated independently of the main control center. A schematic of the sprinkler rise for the grid system is provided.

66 References

Kinnell, P. I. A. 1974. Splash Erosion: Some Observations on the Splash-Cup Technique. Soil Science Society of America Proceedings. 38(4): 657-660. Australia.

Experiments under artificial rainfall conditions showed that the initial, excessive loss from the type of splash cup frequently used in splash-cup experiments were attributable not only to material being pushed sideways over the edge of the cup by the impact of drops near the perimeter of the exposed surface, but also to a decrease in the rate of splash loss.

The artificial rainfall used was produced over a 1 m^2 area from modules containing capillary tubes spaced on a 2.5 cm square grid. The modules were designed to accept drop formers made from hypodermic needles and plastic capillary tubes. This enabled a variety of drop sizes to be made. However, drops less than 3.8 mm equivalent spherical diameter fell in a curved path and were not used. Each of the two artificial rainfalls had a narrow drop size range. The modules were located 11.2 m above the splash cups. Following Laws, the drops at impact were travelling at about 98% of their terminal velocity. Diagrams and graphs are used in explaining the relationship between rainfall and losses from the standard cups plus details of the cups.

7 References

Lattanzi, A. R.; Meyer, L. D.; and Baumgardner, M. F. 1974. Influences of Mulch Rate and Slope Steepness on Interrill Erosion. Soil Science Society of America Proceedings. 38(6): 946-950. Indiana.

Soil and water losses from plots representing field areas between rills were studied for four rates of straw mulch at four slope steepness. Three simulated rainstorms totaling 2 hours at 6.4 cm/hr were applied to a 61 x 61 cm test area.

Rainfall was simulated using an oscillating nozzle at a height of 2.4 m above the soil surface. A square 122 x 122 cm pan was positioned beneath the rainfall simulator. The central square area of 61 x 61 cm served as the plot. The surrounding area served to minimize the border effect. A series of simulated rainstorms totaling 12.8 cm was applied. The initial run lasted 60 minutes. Two 30 minute storms, separated by a 15 minute interval without rainfall were later applied.

Supplementary data on flow velocity, bulk density and related characteristics were obtained but not discussed.

14 References

Law, S. M. 1977. Statistical Evaluation of Rainfall-Simulator. Research Report No. 106. State Project No. 736-03-09. Research Project No. 74-2M(B). Louisianna HPR 1(14). 34p.

A previously developed rainfall simulator (Law and Vaccaro, 1974) was evaluated in this study. The constants for the design and operation of the unit used in this studies were as follows:

1. Test Nozzle - Spraying Systems Company, Fulljet 3/4 HH 50 SQ
2. Height of nozzle - 2.44 meters directly above the center of the test surface.
3. Spray direction - Downward perpendicular to the ground.
4. Water prsssure - 41.4 kPa
5. Water flow - .25 liters per second
6. Water intensity - 54.6 cm/hr
7. Slope angle of test pan - 4°
8. Sampling time - 12 minutes

A water pressure regulator was used to reduce and regulate the line water pressure to a constant pressure of 41.4 kPa (6psi). Also, dual pressure gauges at the nozzle assembly were used to eliminate any chances of erroneous single pressure gauge readings during operation.

Actual construction details of the rainfall simulator, such as materials, framing, bracing, etc., will be subject to change as the builder and/or user sees fit to take care of safety, durability, appearance, ease of construction and ease of operation. In this study the rainfall-simulator was constructed of slotted steel, making the erection simple and low-cost.

Pictures and diagrams of the rainfall-simulator are provided with details of the tests.

11 References

Lusby, G. C. Determination of Runoff and Sediment Yield by Rainfall Simulation. U. S. Geological Survey. 20p. Colorado.

This rainfall simulator is patterned after a rainfall-runoff facility developed and installed at Colorado State University (Holland, 1969). The CSU final design consists of a grid of sprinkler heads sometimes used in lawn sprinkler systems. The sprinklers are supported on 3.05 m risers and operated at a pressure of 28 lb/in^2. Intensity is varied by switching on or off valves controlling input to various sets of sprinklers in the system. These intensities range from about 1.27 to 10.80 cm per hour. The sprinkler head chosen for the facility produces fewer large drops at the higher intensities than is contained in natural rainfall. Although fewer large size drops are present than in natural rainstorms, the uniformity of coverage somewhat offsets this deficit.

The principal components of the portable rainfall simulator used in these studies are the same as those used in the CSU facility. Instead of having several sets of sprinklers to provide different rainfall rates, one set was chosen to produce a rainfall intensity of about 5.08 cm per hour. The grid covers 1.5 acres. Water is supplied to the system through a fire-hose that is supported above the land surface. Sprinkler heads are mounted atop 3.05 m riser pipes and spray upward. Each sprinkler is equipped with a regulator valve set at 28 lb/in^2. The sprinkler grid is positioned over natural drainage basins so that the entire basin is covered by overlapping sprays. The setup provides rainfall over the area of about 3.81 cm in 45 minutes and requires 37,854.12 liters of water. A tank truck is used to supply the water and provide the pumping equipment.

7 References

Lusby, G. C. and Toy, T. J. 1976. An Evaluation of Surface-Mine Spoils Area Restoration in Wyoming Using Rainfall Simulation. Earth Surface Processes. 1: 375-386. Wyoming.

The purpose of this research was to demonstrate the utility of rainfall simulation in collecting data for use in evaluating the effect on surficial hydrology of rehabilitation methods at particular surface-mine sites. The rainfall simulator used in this study is a portable adaptation of the Colorado State University design. In order to reduce the amount of equipment required and to make the apparatus mobile, it was necessary to sacrifice the capability to vary intensity. A rainfall rate of 5.08 cm/hr was chosen because it is not atypical of erosion producing storms in the western United States and produces sufficient erosion for between site comparison.

Sprinklers are arranged in a staggered grid pattern. The spacing in this pattern is 6.10 m along the line and 5.18 m between the lines. The heads are the rotating type and are mounted on 3.05 m riser pipes. Each head assembly is equipped with a pressure regulation valve set at 28 lb/sq.in.

The sprinkler grid and spray patterns are arranged so that approximately 1,066.80 m of area can be covered with the desired rainfall intensity. Water is supplied to the system from a tank truck and a supplemental rubber reservoir. The combined capacities total 37,854.12 liters, which is sufficient to yield a storm of 3.81 cm in 45 minutes. Water is conveyed to the sprinkler assemblies through fire hoses. Standards fabricated from reinforcing bar elevate the hose above the land surface so that it does not impound water. A grid of storage rain gages is placed within the study area to measure the rainfall applied.

9 References

Lyles, L.; Disrud, L. A.; and Woodruff, N. P. 1969. Effects of Soil Physical Properties, Rainfall Characteristics, and Wind Velocity on Clod Disintegration by Simulated Rainfall. Soil Science Society of America Proceedings. 33(2): 302-306. Kansas.

The effects of clod size and density, rainfall intensity and duration, and wind velocity were studied in a laboratory wind tunnel-raintower facility. For a specific clod size and wind velocity, 10 minute rains at 5.61 cm/hr were about as destructive as 90 minute rains at 1.60 cm/hr, even though the total volume of rainfall was 2.5 times larger in the latter case.

Wind-driven rain was very effective in clod disintegration. Up to 66% more soil was lost from clods exposed to 13.4 m/sec winds than those exposed to no wind for the same rain intensity, duration of exposure, and clod size. Mean drop size striking the clods probably increases with wind velocity and would account for some of the wind effects.

Simulated rainfall was applied with full jet nozzles operated at 0.14 to 0.18 kg/cm - about 10.4 m above the soil samples. Size distribution of the simulated raindrops at each intensity was determined by the flour method. Difficulties in accurately measuring rainfall when exposed to wind were overcome by exposing shallow metal trays containing a water-absorbing polyurethane foam material of known area for definite times and weighing it before and after exposure.

9 References

Mazurak, A. P.; Chesnin, L.; Tiarks, A. E. 1975. Detachment of Soil Aggregates by Simulated Rainfall from Heavily Manured Soils in Eastern Nebraska. Soil Science Society of America Proceedings. 39(4): 732-736. Nebraska.

A field experiment was established to measure the effects of annual applications of high rates of manure for the production of crops under irrigation. This paper is a continuation of the studies of Mazurak and Mosher (1968). The samples were exposed to rainfall intensities of 3 cm/hour, 7 cm/hour, and 12 cm/hour. The duration of each simulated rainfall intensity was adjusted so that the total amounts of water or energy applied to the soil samples was nearly the same. The water drops were 5.1 mm in diameter and fell 11.3 mm.

13 References

Mazurak, A. P. and Mosher, P. N. 1968. Detachment of Soil Particles in Simulated Rainfall. Soil Science Society of America Proceedings. 32(5): 716-719. Nebraska.

Detachment of soil particles exposed to simulated rainfall was measured in a rainshaft located in the building. The rainshaft is a 4-story room with inside dimensions of 2.6 x 1.3 m. An applicator-head for simulated rainfall was located on the top floor. It consisted of a stationary 1.2 m diameter tank with raindrop formers protruding from the bottom.

Raindrop formers were constructed from 6 cm length, clear plastic rods. Holes were drilled in the center of each rod with one end having 0.495 mm diameter opening and the other a 3.43 mm diameter opening. A tapered hole connected these openings. Water drops were formed on the larger holes. Droppers with this design gave uniform diameter raindrops with controllable intensity of rainfall. The location of raindrop formers on the bottom were patterned after Palmer.

Distilled water was used for simulated rain which consisted of water drops 5.1 mm in diameter. Raindrops fell 11.33 m onto the soil surface. From this height the raindrops reached 95% of their terminal velocity. Intensities of simulated rainfall were varied by changing the hydrostatic head above the raindrop formers.

8 References

McQueen, I. S. 1963. Development of a Hand Portable Rainfall-Simulator Infiltrometer. Geological Survey Circular 482. 16 p. Washington.

This system has been designed and developed for measuring infiltration of simulated rainfall into small plots of undisturbed soil that can be hand-carried to sites inaccessible to vehicles. This design has eliminated disturbance of surface soil by driven plot frames or cylinders, a primary source of errors in infiltration measurements. Water requirements have been reduced to 3.79 or 7.57 liters per measurement; so, distilled water or controlled chemical solutions can be used. Accurate measurements can be made rapidly and economically. The drop size is 5.6 mm with an energy of $0.137 j/cm^2/cm$ on a plot size of 76.12 sq cm. The range of rate is from 2.54-38.10 cm with a normal rate of application of 10.16 cm. Details of the rainfall simulator are given with the aid of diagrams and photographs. A comparison is made among this the Rocky Mountain infiltrometer and two other infiltrometers.

9 References

Meeuwig, R. O. 1969. Infiltration and Soil Erosion as Influenced by Vegetation and Soil in Northern Utah. Journal of Range Management 23(3): 185-188. Utah.

The influences of vegetation, soil properties, and slope gradient on infiltration capacity and soil stability of high-elevation herbland on the Wasatch Front in northern Utah were investigated under simulated rainfall conditions. Results emphasize the importance of vegetation and litter cover in maintaining infiltration capacity and soil stability.

The rainfall-simulating infiltrometer described by Dortignac (1951) was used to apply 6.35 cm of simulated rain to each of eighty 50.80 by 76.20 cm plots during a 30 minute period.

7 References

Meyer, L. D. 1963. Simulation of Rainfall for Soil Erosion Research. American Society of Agricultural Engineers. No. 63-724: 63-65. Indiana.

Simulated rainfall has become an important research tool for erosion studies. It is generally more rapid, efficient, controlled, and adaptable than natural rainfall. It can therefore replace natural rainfall for many studies. For soil erosion research, simulated rainfall equipment should closely approach certain characteristics if the studies are to produce reliable indications of natural rainfall effects. Some of the more important of these are: Drop size distribution and fall velocities near those of natural rainfall at comparable intensities, intensities in the range of storms producing medium to high rates of runoff and erosion, application area of sufficient size for satisfactory representation of treatments and erosion conditions, uniformity of intensity and drop characteristics, rainfall application continuous throughout the test plot, operation that is accurate in winds, and complete portability. Simulated rainfall is a valuable research tool having the potential for improving our knowledge of soil erosion.

10 References

Meyer, L. D. 1960. Use of the Rainulator for Runoff Plot Research. Soil Science Society Proceedings. 24(4): 319-322. Indiana.

The portable rainfall simulator, known as the rainulator, developed at Lafayette, Indiana, was designed for use as a research tool to aid in more rapidly evaluating factors that influence erosion, runoff, and infiltration. The rainfall simulator embodies the following characteristics:

1. Complete portability.
2. Variation in size of plots covered.
3. Variation in number of plots covered simultaneously.
4. Drop size distribution near that of natural rainfall.
5. Drop velocity of fall near that of natural rainfall.
6. Kinetic energy at impact approximately 80% that of corresponding natural rainfall.
7. Intensities in the range of storms producing medium to high rates of runoff and erosion (6.35 and 12.70 cm per hour).
8. Use of standard runoff and soil loss measuring equipment.
9. Satisfactory operation in wind velocities of less than 15 mph.
10. Ability to reproduce specific simulated storms.

Also, certain limitations on the use of the rainulator must be recognized. Comparisons which are not adopted to evaluation with a constant application intensity and impact energy should not be studied. Runs cannot be conducted when the water in the lines and fittings will freeze. The rainulator is not designed for use on plots wider than 4.27 m. Careful selection of the period or periods during a year when runs are made on treatments whose effects vary with time due to crop cover, moisture condition, or other reasons is essential to secure valid comparisons.

21 References

Meyer, L. D. and Harmon, W. C. 1977. Rainfall Simulator for Evaluating Rates and Sediment Sizes from Row Sideslopes. American Society of Agricultural Engineers. No. 77-2025. 7p. Mississippi.

To evaluate row sideslope erosion for different types of typical conditions, a new rainfall simulator was developed. It can apply a wide range of intensities at impact energies comparable to natural rainfall.

The frame for this rainfall simulator includes telescoping legs, quick connect water fittings, and electrical connectors. Two persons can readily assemble and disassemble the equipment.

The plot size and arrangement depends on the conditions being evaluated. Size distribution, drop diameter, impact energy, and rainfall intensity are discussed through the use of graphs.

No References

Meyer, L. D. and McCune, D. L. 1958. Rainfall Simulator for Runoff Plots. Agricultural Engineering. 39(10): 644-648. Indiana.

A portable rainfall simulator developed at Purdue University produces artificial storms of approximately the kinetic energy of high intensity natural rainfall. The final design for the nozzles and their operation was:

1. Nozzle - Spraying Systems Company 80100 VeeJet.
2. Height - 2.44 m above soil surface.
3. Spray Direction - Downward, perpendicular to the soil surface.
4. Nozzle Pressure - 4 gpm per nozzle.
5. Distance between nozzles - 1.52 m parallel by 1.83 m perpendicular to the long dimension of the spray pattern.
6. Distance nozzles are spraying during movement - 1.83 m.
7. Type of movement - Reciprocating, with nozzles moving back and forth across slope.
8. Intensities - 6.35 cm/hr (each nozzle spraying 20% of time) and 12.70 cm/hr (each nozzle spraying 40% of time).

The kinetic energy produced by this design is approximately 800 ft-tons per acre-inch, or greater than 75% of the kinetic energy of natural rainfall at an intensity of 6.35 cm/hr, which is considered sufficient. Each unit can cover a plot that is 4.57 m long by 3.66 m wide with a .91 m border on both sides.

Details of the framework, drive mechanisms, and the water supply are given with the aid of diagrams and pictures.

19 References

Meyer, L. D.; Wischmeier, W. H.; and Daniel, W. H. 1971. Erosion, Runoff and Revegetation of Denuded Construction Sites. Transactions of the American Society of Agricultural Engineers. 14(1):138-141.

The plots for this study were 3.66 m across slope by 10.67 m long, separated by 1.83 m border areas. They were arranged in a randomized block design that permitted application of simulated rain (Meyer, 1960) to all six treatments in one replication during one day. All operations involved in applying the treatments were up and down slope. Simulated rainstorms totaling 12.70 cm were applied at an intensity of 6.35 cm per hour. The initial storm last 60 minutes. Two 30 minute runs, separated by 15 minutes, were made the following day. Rainfall intensity, runoff, and soil loss were evaluated in the standard manner (Meyer, 1960).

The data were adjusted for small deviations from the design intensity of 6.35 cm/hr. Runoff data were modified by the amount the actual application differed from 6.35 cm for the initial run or 3.18 cm for the 30 minute run.

24 References

Moldenhauer, W. C. and Long, D. C. 1964. Influence of Rainfall Energy on Soil Loss and Infiltration Rates: Effect over a Range of Texture. Soil Science Society of America Proceedings. 28(6):813-817. Iowa.

Soil and water losses were determined from sieved air-dry samples of five Iowa soils varying in texture using a laboratory rainfall simulator described by Mutchler and Moldenhauer (1963). Drop diameter varied between 4.84 and 5.00 mm over the intensities ranging from 3.43 to 6.78 cm per hour. The intensities were constant during each run. The height of fall was 3 m. The relationship between soil loss and rainfall intensity for each of the five soils is explained with the use of graphs.

16 References

Moldenhauer, W. C.; Lovely, W. G.; Swanson, N. P.; and Currence, H. D. 1971. Effect of Row Grades and Tillage Systems on Soil and Water Losses. Journal of Soil and Water Conservation. 26(5):193-195. Iowa.

Three tillage methods were compared for their effectiveness in controlling soil and water losses with up-and-down-hill planting on a range of slopes from 3.4 to 9 percent using a rotating-boom rainfall simulator.

Three simulated storms were applied to each plot with a rotating simulator. A 6.35 cm-per-hour storm with a 1.4 hour duration was followed 24 hours later by a 6.35 cm-per-hour storm with a 1 hour duration. After a 15 minute delay for sampling and setup, the final storm, 12.70 cm per hour with a duration of 0.3 hours, was applied. The runoff and erosion sampling procedure was the same as used by Swanson (1965).

15 References

Morin, J.; Cluff, C. B.; and Powers, W. R. 1970. Realistic Rainfall Simulation for Field Investigation. Water Resources Research Center, University of Arizona. 22 p. Arizona.

The purpose of this paper is to describe the construction of a field simulator using the principle of a rotating disk that would be suitable for determination of infiltration rate in the field and compare this simulator's characteristics with other well known models. The unique feature of the rotating disk is the rotation of disks with various size openings that makes it possible to produce intensities from close to zero up to the full nozzle capacity. Disks can be changed in the field in less than one minute, making it possible to study the effect on infiltration rates of a series of intensities such as occur in natural storms. With these disks, intensities ranging from 17 mm/hr to 152 mm/hr can be obtained. The rainfall is virtually continuous. Kinetic energy and momentum of raindrops are very near that of natural rainfall. Drop diameter is also very near that of natural rainfall. A plot of 2.1 meters diameter is wetted by this nozzle.

The frame supporting the water distribution assembly is constructed out of 31.75 mm aluminum pipe. A wind shield of reinforced clear plastic is used which allows enough light for photography work. The water distribution assembly, frame, and curtain is light enough for two men to carry; however, bicycle wheels were mounted to the frame in order that one man can move and operate it. One man can make an average of four 1-hour runs in an 8-hour day. This includes plot preparation, moving, and setting up the simulator.

Charts and graphs are used to compare this and other rainfall simulators.

13 References

Morin, J.; Goldberg, D.; and Seginer, I. 1967. A Rainfall Simulator with a Rotating Disk. Transactions of the American Society of Agricultural Engineers. 10:74-77. Israel.

A rainfall simulator by means of which intensity, median drop size and drop velocity can be controlled over a fairly wide range is described in this paper. The simulated rain covers uniformly an effective area of about 1.5 square meters. Drop-size distribution with a high proportion of large drops at near their terminal velocity are obtained by using high discharge, wide angle, and full cone nozzles. Rainfall intensity is controlled by mounting a rotating disk with a section aperture below the downward spraying nozzle. Thus the nozzle discharge can be stepped down to as little as 1.5 percent of the original quantity. Disk speeds can be set at 1/2, 4, 30 and 200 rpm, the low speeds simulating irrigation conditions and the high speeds continuous rainfall. The system is mobile and can be adapted for field work. Intensities from 8 to 143 mm/hr were achieved.

No References

Munn, D. A.; McLean, E. O.; Ramirez, A; Logan, F. J. 1973. Effect of Soil, Cover, Slope, and Rainfall Factors on Soil and Phosphorous Movement Under Simulated Rainfall Conditions. Soil Science Society of America Proceedings. 37(3):428-431. Ohio.

Three soils were treated with phosphorous at 25, 125, and 625 ug P/g soil in bare and cropped microplots and subjected to simulated rainfall.

A sprinkling device for the simulated rainfall was built like that of the Purdue Sprinkling Infiltrometer, Bertrand and Parr (1961) and was calibrated to give 6.35 cm/hr and 12.7 cm/hr using Model 5B and 7LA nozzles at 25 and 10 psi, respectively. The sprinkler head was 274 cm above the surface of the microplots. Calibration was done empirically at each rain intensity. The microplots were 122 cm long by 30.4 cm wide.

14 References

Munn, J. R., Jr. and Huntington, G. L. 1976. A Portable Rainfall Simulator for Erodibility and Infiltration Measurements on Rugged Terrain. Soil Science Society of America Proceedings. 40(4):622-624. California.

The rugged terrain of mountainous areas requires that a useful rainfall simulator be adaptable to a wide range of slopes. Economy of water use is desirable due to the uncertain nature of water supplies. Also, project manpower is often a restriction, so the equipment must be simple to assemble and operate. The final requirement is that the apparatus produce simulated storms with a reasonable relationship to natural rainfall.

The Tahoe Basin rainfall simulator is designed for use over 61 x 61 cm plots. Water is suppled by a 20 liter reservoir that sits above an airtight rainfall chamber from which 827 drop forming tubing tips extend. The rainfall unit is supported by a lightweight frame that provides a drop fall of 2.5 m and that can be adjusted to fit slopes up to 60 percent.

The rainfall chamber is similar to that described by Chow and Harbaugh (1965) and allows instantaneous changes in the simulated rainfall intensity. Overall dimensions are 76 x 76 x 2.5 cm, and the drop formers cover a 71 x 71 cm area. The drop formers are 2.2 cm long sections cut from 0.058 cm inside diameter and 0.097 cm outside diameter polyethylene catheter tubing. These tubes produce 3.2 mm diameter drops.

The kinetic energy (KE) produced by the falling drops is 1.7×10^6 joules per ha-cm of simulated rainfall. According to Wischmeier and Smith (1958), a natural storm delivering the same energy per unit volume of rainfall has an intensity of 0.43 cm per hour.

17 References

Mutchler, C. K. and Hermsmeier, L. F. 1965. A Review of Rainfall Simulators. American Society of Agricultural Engineers. No. 63-726:67-68. Minnesota.

Rainfall simulators for erosion-control research use one of three methods for forming waterdrops. Hanging yarn and tubing-tip drop formers are limited to use in laboratory simulators. Nozzles offer the best opportunity to duplicate the drop distribution of rainfall and are best suited for large-plot erosion studies. Development of a nozzle (and rainfall simulator) that will allow more precise rainfall simulation is needed.

However, to date, the most suitable nozzle for rain simulation has been the 80100 VeeJet commercial nozzle tested and used by Meyer and McCune in the simulator called Rainulator. The nozzle at 6 psi line pressure produces a drop-size distribution similar to that of rainfall. The median drop-size, based on volume, is about 2-1/8 mm compared with 2-1/2 mm of rainfall at an intensity of 5.08 cm/hr. Kinetic energy developed by the nozzle at 2.44 m height as used in the Rainulator is about 80 percent of that of simular intensity rainfall. Also, the spray pattern is adaptable to use in a multi-nozzle rainfall simulator.

31 References

Obeid, M. and Din, A. S. E. 1971. Ecological Studies of the Vegetation of the Sudan. III. The Effect of Simulated Rainfall Distribution at Different Isohyets on the Regeneration of Acacia Senegal (L.) Willd. on Clay and Sandy Soils. Journal of Applied Ecology. 8(1):203-209. Sudan.

An experiment was set up to include seven simulated rainfalls for sandy soils (ranging from 200-500 mm) and eight for the clay soils (ranging from 300-600 mm). Tins (20 x 20 x 15 cm) were filled with the corresponding type of soil. One liter of water, homogeneously spread over 1 m^2 is equivalent to 1 mm of rainfall. Using this, the corresponding shower to be added to each of the tins was calculated.

5 References

Packer, P. E. 1957. Intermountain Infiltration. USDA Misc. Pub. No. 14.

The Intermountain Type-F Infiltrometer is a portable set of apparatus for applying artificial rainfall at either constant or variable rates up to 15.24 cm per hour on a sloping area about 2.74 x 2.74 m in size, and for collecting and measuring resultant surface runoff and eroded soil from three .61 x 1.83 m plots within the wetted area. Infiltration rates can be determined from the difference between rates of applied rainfall and runoff.

Two men working as a team can set up this apparatus for field operation. The instructions for assembly and operation are illustrated by a series of photographs taken in the field. A complete list of parts, together with their dimensions and specifications, is therefore included in the publication.

13 References

Rauzi, F. and Smith, F. M. 1973. Infiltration Rates: Three Soils with Three Grazing Levels in Northeastern Colorado. Journal of Range Management. 26(2):126-129. Colorado.

These studies used a mobile infiltrometer (Rauzi et al, 1968) to apply simulated rainfall. The area this was applied to was a circular area of approximately 3.96 m sq. The test plot was .61 m square and located in the center of the circular area receiving the simulated rainfall. Rainfall was applied to the test plots for 1 hour. The simulated rainfall was constant for each plot but varied between 6.35 and 8.89 cm/hr among all the plots.

14 References

Rawitz, E; Margolin, M; and Hillel, D. 1972. An Improved Variable Intensity Sprinkling Infiltrometer. Soil Science Society of America Proceedings 36:533-535. Israel.

Improvements of the Purdue-Wisconsin infiltrometer are described. A winch has been added for lifting into place the shutter assembly and its motor and gearbox to facilitate assembly. The frame is given rigidity by diagonal cable struts tightened by turnbuckles. This eliminates the need for external guy ropes and pegs. An impregnated canvas windshield was constructed to order by a tent manufacturer.

The lower disk of the shutter was flanged only at the leading edge of the openings, since the flange at the trailing edge apparently intercepted and deflected an appreciable number of water drops. The collecting trough was completely redesigned to eliminate drippage onto the test plot. The new, sloping lower trough surface allows an unimpaired flight path of all water drops with a return of the excess to the main water reservoir. The nozzle levelling assembly utilizes a Spraying Systems adjustable mount with a ball joint. A small bull's-eye level was fastened onto the base plate of this mount.

The water is pumped from a portable reservoir by a Hypo Model N4000 pump powered by a 0.6 hp electric motor. The pressure is regulated by a Sprayings System Model "9480-1/2" pressure regulator which recirculates excess water to the main tank. The delivery hose is a 13 mm (1/2 inch) PVC nylon-reinforced light-weight hose of the type used in agricultural sprayers.

Runoff water is removed through a perforated pipe (Dixon and Peterson, 1968). A partial vacuum is maintained in the runoff collection tank by a milking machine suction pump powered by a 0.6 hp electric motor. Pressure in the tank is regulated by a vacuum regulator.

Power is supplied to all motors and instruments by a 2.5 KVA gasoline engine power portable generator. All circuits are controlled from a central waterproof control panel with a separate switch and magnetic overload fuse for each circuit.

10 References

Romkens, M. J. M.; Glen, L. F.; Nelson, D. W.; and Roth, C. B. 1975. A Laboratory Rainfall Simulator for Infiltration and Soil Detachment Studies. Soil Science Society of America Prodeedings. 39(1):158-160. Indiana.

A laboratory rainfall simulator with high intensity precision and nearly uniform rain distribution was developed for studying rain infiltration into soils and soil detachability by rainfall. The rainfall simulator consists of an assembly of closely packed hypodermic syringes with plungers driven by a common plate. Rainfall intensity is determined by controlling the plunger speed at variable motor speeds. Rain is distributed uniformly by superpositioning three independent motions - rotation and perpendicular and linear motions in the horizontal plane. Rainfall intensities were generally within 2.5 percent of predicted values. The average coefficient of variation of rain distribution for various rainfall intensities over a 100 cm^2 area was reduced from 31.9 percent with no motion to 8.5 percent with rotation and linear motions. The experimental area can be enlarged by increasing the number of syringes in the rainfall simulator. Drop diameters can be varied by changing needle size and rainfall capacity can be increased by using longer syringe barrels. A schematic representation of the rainfall simulator is provided.

No References

Rose, C. W. 1960. Soil Detachment Caused by Rainfall. Soil Science. 89:28-35. Uganda.

The aims of these experiments were to investigate the quantitative relationships between soil detachment and the physical characteristics of rainfall; namely, the rainfall rate, drop size, impact velocity, and duration, and to find out what overall physical property of the rainfall governs the amount of detachment caused. Equipment for the simultaneous exposure of 10 samples to laboratory-produced rainfall was constructed. The raindrop producer could be fitted with any of four sets of drop producers, which covered the size range 3.2-6.2 mm equivalent spherical diameter.

The rainfall rate could be varied by altering the number of droppers, and by changing the head of water above the drops (though this affects drop size). By altering the height of the rain producer above the samples, the velocity with which drops hit the soil surface could be varied. The height was maintained at 6 m.

Rainfall durations of 15, 30, and 50 minutes at a rate of 5.08 cm per hour; for durations of 15 and 30 minutes at 10.16 cm per hour; and for 15 minutes at 15.24 cm per hour were used.

15 References

Selby, M. J. 1970. Design of a Hand-Portable Rainfall-Simulating Infiltrometer, with Trial Results from the Otutira Catchment. Journal of Hydrology. 9(2):117-132. New Zealand.

An instrument has been constructed, based on a United State Geological Survey design, which requires only one man and little water to run tests. It is rugged in construction, does not disturb the soil, and can be used on slopes. The instrument consists of a raindrop maker designed as a box with a thick base through which are drilled 91 holes. In each hole is a wire which protrudes through the countersunk lower end of the hole as a drop former. This can be adjusted to give intensities of 20 to 300 mm/hr. The raindrops fall on to a small circular plot (14 cm diameter) from which surface and splash water can be sucked off. The raindrop maker has a constant head of water supplied by a reservoir. Initial tests of the instrument indicated the accuracy of the instrument.

18 References

Sloneker, L. L. and Moldenhauer, W. C. 1973. Effect of Varying the On-Off Time of Rainfall Simulator Nozzles on Surface Sealing and Intake Rate. Soil Sci. Soc. Amer. Proc. Vol. 38(1):157-159. Minnesota.

An experiment was conducted at Morris, Minnesota to investigate the possible effects of nozzle on-off time on rainfall simulator results. One VeeJet 80100 nozzle was mounted on a carriage that made one complete traverse of the plot every 10 seconds. The time interval between nozzle sprays over the plot area was varied from 10 to 20 to 40 seconds and resulted in application rates of 8.4, 4.3, and 2.4 cm/hr, respectively. The kinetic energy (KE) of a specified amount of the simulated rainfall with a water pressure of 422 g/cm^2 was a constant (21107.2 $joules/m^3$) regardless of intensity. Therefore, total amounts of KE are functions of total amounts of water applied regardless of application rates.

Tables are given indicating that a rest period greater than 10 seconds between spray applications afforded the soil enough recovery time to delay surface sealing. More than twice the amount of energy was applied to initiate runoff on the lowest than at the highest application rate. The results of this experiment showed definitely that energy to initiate runoff increased as the nozzle off time increased above 10 seconds. The results also showed that in the range of application rates tested and with the smoothest possible surface, intake rate increased as application rate increased.

8 References

Sloneker, L. L.; Olson, J. C.; and Moldenhauer, W. C. 1974. Soil-Water Pressure During Intermittent Simulated Rain Application Measured with a New Rapid-Response Tensiometric Technique. Soil Sci. Soc. Amer. Proc. 38:985-987. Minnesota.

A method is described for measuring instantaneous changes in soil-water pressure in soil beds during intermittent application of simulated rainfall. Intermittent off periods between nozzle on times affected soil-water pressure which influenced the accumulated rainfall energy required to initiate runoff. The procedure used was essentially that reported by Sloneker and Moldenhauer (1974), and is thoroughly explained in this text.

These results, shown through graphs and tables, demonstrate how soil-water pressure can vary when the soil is subjected to intermittent rainfall. It would not have been possible to measure these rapid pressure changes using conventional tensiometer construction. The technique described can be used to measure rapid changes in soil-water pressure under near saturated conditions.

1 Reference

Steinhardt, R. and Hillel, D. 1966. A Portable Low-Intensity Rain Simulator for Field Use and Laboratory Use. Soil Science Society of America Proceedings. 30:661-663. Israel.

A design is presented for construction of a dripping-type rain simulator that is useful for study of infiltration characteristics of surface-crusted soils and comparisons of surface treatments for runoff inducement. The apparatus is lightweight (25 kg), portable and easy to assemble. Designed for both laboratory and field use, it can simulate rain with an intensity as low as 4 and as high as 100 mm/hr. The rain is applied randomly and uniformly over a 70 by 70 cm plot. Rainfall characteristics, such as raindrop size and impact velocity (as well as intensity), can be controlled and varied independently. To permit infiltration-runoff tests in the field, a test-plot boundary frame and runoff-collection trough have also been developed.

A square-bottom water tank is suspended from a lightweight aluminum frame assembly. The bottom of the tank consists of soft rubber sheet confined between two perforated steel plates. Stainless steel capillary tubes, inserted through the rubber into the water tank, drip the rain. The tank can be set at various heights to obtain different raindrop impact velocities. It is supplied with water by a variable-discharge pump. Raindrop size can be varied by inserting capillaries of different tip-diameters. Rainfall intensity can be varied by changing the number of dripping capillaries per unit area and their sizes, as well as adjusting the discharge rate of the pump. In order to randomize raindrop distribution over the soil surface, an eccentric rotor is set on top of the frame (to rotate the tank during operation).

When operated in the field, a 50 by 50 cm test-plot boundary frame is placed on the soil under the rain simulator. A knife-edge collecting trough is inserted into the downslope edge of the test plot. The same pump which supplied water to the tank sucks the runoff out of the trough and discharges into a container with a stage recorder.

11 References

Swanson, N. P. 1965. Rotating-Boom Simulator. Transactions of the American Society of Agricultural Engineers. 8:71-72. Nebraska.

This paper describes a trailer-mounted simulator developed at Lincoln, Nebraska. Rotating booms are utilized to carry continuously spraying nozzles that have retained the desired characteristics for a plot rainfall simulator developed by Meyer (1960). The associated equipment required and the techniques employed for field plot use are essentially the same for the rotating-boom simulator as for the rainulator which have been described by Hermsmeier, Meyer, Barnett, and Young (1963). The simulator utilizes 10 booms to support 30 nozzles. Intensities of 6.35 and 12.70 cm are obtained by operating 15 or 30 nozzles, which are the 80100 VeeJet nozzles. Two plots 10.67 x 4.27 m and 3.05 m apart can be accommodated by one simulator.

The simulator can be trailed behind a vehicle or tractor for local moves over the road. This would require only the disassembly of the booms and cables which can be accomplished is less than 30 minutes. The booms can be attached and leveled in 2 hours. Long-distance moves justify further disassembly for transportation on a truck or trailer. Three or four men can disassemble and load a simulator in 2 hours. Unloading, assembly, and servicing can be accomplished in 3 hours.

The rotating boom simulator has certain inherent undesirable characteristics. The cycling of simulated rainfall varies over a plot; the nozzle heights are lower over the upper end of the plots and water is distributed in a circular pattern requiring protection for immediately adjacent plots. These characteristics, however, have neither visibly affected the results obtained nor proven to be problems in the use of the simulator.

4 References

Swanson, N. P. and Dedrick, A. R. 1967. Soil Particles and Aggregates Transported in Water Runoff Under Various Slope Conditions Using Simulated Rainfall. Transactions of the ASAE. 10(2):246-247. Nebraska.

The primary objectives of the study reported here were to determine whether the aggregate-size distribution of the eroded soil changes throughout a simulated rainstorm and to compare aggregate-size and particle-size distributions of the material eroded for varying degrees of land slope.

The plot slopes selected were 3, 7 and 12 percent. Each plot was 10.67 m long and 3.66 m wide. A rotating-boom rainfall simulator (Swanson, 1965) was used for all tests. Results are reported for two simulated rainstorms, with durations of 1.4 and 1.0 hr and an intensity of 6.35 cm per hour for storm 1 and 2, respectively. The simulated rainstorms were applied simultaneously to pairs of plots. Runoff-measuring equipments and battery-powered samplers designed by Meyer and reported by Hermsmeier et al (1963) were used.

7 References

Swartzendruber, D. and Hillel, D. 1975. Infiltration and Runoff for Small Field Plots Under Constant Intensity Rainfall. Water Resources Research. 11(3):445-451. Israel.

The purpose of this paper is to analyze the infiltration and runoff behavior of a small field plot on uniform and stable soil subjected to constant intensity simulated rainfall. A modified Purdue-Wisconsin device (Rawitz et al, 1972) was used to apply the simulated rainfall to an area of 10 m^2 at the center of which a plot 1 x 1 m was delimited by 20 cm high frames inserted 12 cm deep into the soil. A perforated tube was placed at the lower edge of the plot to gather the runoff by suction.

In one set of experiments, simulated rainfall was applied at a constant intensity of 1.037 mm/min for two different applications. The third application was reduced to .500 mm/min. The field data were utilized successfully for obtaining the ultimate steady infiltration flux, even when the period of measuring transient runoff was less than 1 hour and the total runoff less than 1 cm of water. The value of steady flux so obtained was in good agreement with that found under the condition of continuous ponding of water on the soil surface.

8 References

Tromble, J. M.; Renard, K. G.; and Thatcher, A. P. 1974. Infiltration for Three Rangeland Soil-Vegetation Complexes. Journal of Range Management. 27(4):318-321. Arizona.

A rotating disk rainfall simulator developed by Morin (1967, 1970) was used to examine infiltration-runoff relations from selected rangeland sites as influenced by a soil-vegetation complex. A 4.45 cm per hour rate of application was used on the 129.54 sq-cm plots.

8 References

Turner, A. K. and Langlord, K. A. 1969. A Rainfall Simulator and Associated Facilities for Hydrologic Studies. The Journal of the Australian Institute of Agricultural Science. 35(2):115-199. Australia.

The simulator described is based on a rainfall simulator developed by Meyer (1958) at Purdue University. For the purpose of this study, the following modifications were made:

1. The machine should water four plots 4.57 m x 4.57 m, two plots 10.67 m x 4.57 m or one plot 22.86 m x 4.57 m.
2. The drop-size and velocity spectra of a second nozzle, VeeJet 8070 (operating also at 6 p.s.i. from a height of 2.44 m) are compatible with those of medium intensity rainfall; by using this alternative nozzle, another three intensities are available.
3. The electrical control system was redesigned to give instantaneous switching from one intensity to another, for the particular nozzle in use.
4. A recycling system was provided for the water removed from the supply system during the dwell periods.
5. New working drawings were needed to allow for the different structural sections available in Australia.

A concrete bin 27.43 m x 4.57 m was built and filled with soil to a depth of approximately 1.07 m with a surface slope of 2-1/2 percent and a relatively uniform soil density. The rainfall simulator can be constructed over this bin, and cultivation treatments tested. Plans exist for erecting a glasshouse over the soil bin and the provision of climate control equipment.

7 References

White, A. W., Jr.; Asmussen, L. E.; Hauser, E. W.; and Turnbull, J. W. 1976. Loss of 2,4-D in Runoff from Plots Receiving Simulated Rainfall and from a Small Agricultural Watershed. Journal of Environmental Quality. 5(4):487-490. Georgia.

The rainfall applicator for this study was made of four 2.5 cm pipes (7.3 m long) with T-jet nozzles spaced every 46 cm. The pipes were mounted 1.5 m above the ground over four rows with the nozzles directed downward. City water was used for the water supply and flow rates were controlled with pressure regulators. Three four-row plots, 30.2 m^2 in size and adjacent to each other, were prepared near the watershed edge. Rainfall was applied at a rate of 16.5 cm/hr for 30 minutes.

24 References

Williams, G. and Gifford, G. F. 1969. Analysis of Hydrologic, Edaphic, and Vegetative Factors Affecting Infiltration and Erosion on Certain Treated and Untreated Pinyon-Juniper Sites. Ph.D. Dissertation. Utah State University. 172 p. Utah.

The Rocky Mountain Infiltrometer is used in this study. This infiltrometer is suited for infiltration experiments with its mobility and ease of plot installations. The infiltrometer is equipped with three type F nozzles mounted on a 66.04 cm high frame. Those nozzles produce raindrops of approximately 3.2 to 5.0 mm in diameter which are considerably larger than raindrops from a rainstorm of similar intensity. The nozzles sprinkle an area of approximately 3.05 m in diameter, thereby providing a buffered area of approximately .91 m in width which surrounds the plot. This buffered area minimizes the effect of lateral movement of subsurface water from the plot area.

A diagram and pictures of the Rocky Mountain Infiltrometer are provided. A comparison is made between the Rocky Mountain Infiltrometer and a ring infiltrometer, finding the former superior for this study. A drip tower sprinkling infiltrometer was also found unsatisfactory.

102 References

Wischmeier, W. H. and Mannering, J. W. 1965. Effect of Organic Matter Content of the Soil on Infiltration. Journal of Soil and Water Conservation. 20(4):150-152. Indiana.

A rainulator study was begun in 1960 to relate infiltration and soil erodibility to various soil properties for which numerical measurements can be readily obtained in the field or laboratory. The rather widely scattered test sites were selected over a broad range of soil types and textures. All test plots were uniformly prepared for testing in fallow and were subjected to identical simulated rainstorms. A 6.35 cm "initial run," usually beginning with soil moisture near field capacity, was followed about 24 hours later by two 30 minute "wet runs" on the same plots. All three storms were at a uniform intensity of 6.35 cm per hour.

No References

Yen, B. C. and Chow, V. T. 1969. A Laboratory Study of Surface Runoff Due to Moving Rainstorms. Water Resources Research. 5(5):989-1006. Illinois.

In this study the importance of the movement of rainstorms on the time distribution of the surface runoff from watersheds is demonstrated through the use of a laboratory watershed experimentation system (WES). The size of the basin of the WES is 12.19 m by 12.19 m; in this area the 9.75 square m experimental watershed is located. The artificial rain falling on the watershed is produced by 400 raindrop producers as described by Chow and Harbaugh (1965). Four raindrop producers form a module covering 4.88 sq-m and are connected to a common electronic digital valve assembly (EDVA). By electronically controlling the open or closure of the valves, fifteen different intensities of rainfall for any desired duration can be attained to cover each 4.88 sq-m module independently.

In this study the raindrops were of almost equal size, 3.56 mm diameter, being uniformly distributed in space and falling vertically to the watershed surface. Two intensities of 8.89 and 17.02 cm/hr. were tested. Fourteen different velocities are used.

Through controlled laboratory experiments with uniformly moving rainstorms having uniform rainfall intensity and duration equal to the time required for the rainstorm front to move across the impervious square watershed, the importance of the movement of the rainstorm on the characteristics of surface runoff hydrograph of a watershed has been demonstrated. A list of seven conclusions is given.

13 References

Yerkhov, N. S. 1975. Method for determining pressureless soil permeability during sprinkling. Soviet Soil Science. 7(5):624. USSR.

The method developed on the basis of a theoretical analysis of rainfall infiltration into the soil and of experimental investigations of pressureless water infiltration during sprinkling is described. It consists essentially of determining the "index of pressureless soil permeability during sprinkling" in the field using a special moving sprinkler. The rainfall intensity at which the assigned irrigation rate enters the soil until puddles form on its surface is determined from this index for a given drop size.

No References

Young, R. A. and Burwell, R. E. 1972. Predictions of Runoff and Erosion from Natural Rainfall Using a Rainfall Simulator. Soil Sci. Soc. Amer. Proc., Vol 36(5):827-830. Minnesota.

A comparison was made of the soil and water losses from three natural storms and three simulated storms on cultivated fallow plots under similar rainfall and soil conditions. A rainulator was used to apply the simulated storms to the 22.13 m x 4.06 m plots at the rates of 3.18, 6.35, and 12.70 cm/hr. The kinetic energy discharged by the nozzles was 84 percent, 76 percent, and 70 percent, respectively, of that of similar intensity rainfall. Soil losses from the three simulated storms averaged 77 percent of those from the natural rainstorms. This compares closely, considering that the EI value for the simulated storm was 78 percent of that for the natural rainstorms.

The study showed that, in general, the rainulator can be used to simulate rainfall for runoff and erosion research with confidence that the results will reflect the runoff and soil loss that would occur under similar conditions of natural rainfall.

6 References

Young, R. A. and Mutchler, C. K. 1969. Soil Movement on Irregular Slopes. Water Resources Research. 5(5):1084-1089. South Dakota.

Soil loss and runoff were measured from concave, uniform, and convex slopes subjected to simulated rainfall. Standard rainfall simulator procedures (Meyer, 1960) were used to obtain runoff and soil loss measurements. Plots were 4.06 m by 22.86 m and had an average slope of 9 percent. Simulated rainfall was applied at an intensity of 6.35 cm per hour in four half-hour increments, with about one hour between applications. Wind velocity and direction, air temperature, water temperature, and relative humidity immediately before each run were also recorded. Fluorescent glass particles and microrelief measurements were used to determine soil movement patterns in the slopes.

11 References

Zingg, A. W. 1940. Degree and Length of Land Slope as it Affects Soil Loss in Runoff. Agricultural Engineering. 21(2):59-64. Missouri.

A group of eight plots with two lengths, 2.44 and 4.88 m, are represented for this study. All plots were 1.07 m wide. The rain simulator developed at the Bethany station and described by Woodruff, Smith, and Whitt was used to apply water to the plots. A rainfall rate of 8.00 cm per hour was applied for a 45 minute period for all tests made. The one intensity was used due to the fact that drop size will vary with changes in pressure head, for the type of rain simulator used, introducing a variable in addition to variation of the intensity of rainfall.

10 References

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Wischmeier, W. H., and D. D. Smith. 1958. Rainfall energy and its relationship to soil loss. Trans. Am. Geophys. Union. 39:285-291.

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